Marine Corps Systems Command
Combat Support Logistics Equipment and Training Systems Directorate
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Reconnaissance Surveillance Targeting – Vehicle (RST-V) Concept/Requirements Report

Reconnaissance Surveillance Targeting – Vehicle (RST-V) Concepts/ Requirements Report

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13. ABSTRACT ***(Maximum 200 words)***

This report is considered to be an interim report for the RST-V Study Contract.

The basic top level objectives of this RST-V Study are to: 1) Identify concepts, architectures, and technologies supportive of the RST-V System/Segment Specification (DRAFT, Revision 03, 26 March 1996); 2) Identify those currently defined requirements that are not considered to be realizable with technologies that are either available now or will be available for effective use within the RST-V Advanced Technology Demonstrator (ATD) which is scheduled for fabrication and initial testing in FY 1999; 3) Provide definition and availability estimates for technologies supportive of RST-V Specification requirements. Technology availability will be categorized into three time frames: a) Can be built today or is relatively low risk for RST-V ATD; b) Can support RST-V ATD upgrades (3-5 years out); c) Can only support developments beyond five years out.

This report summarizes RST-V Study progress to date and focuses on the following topics which were suggested at the RST-V Kickoff Presentation held on April 16, 1996: Requirements Analysis; Mission Analysis; Concepts Developed; System Trade Studies; and, Vehicle Weight Analysis.

14. SUBJECT TERMS

RST-V	ATD	LMDS/GDSS
Hybrid Electric Drive	System Trade Studies	Vehicle Weight Analysis
RST-V Study	Standard Propulsion System	Survivability
Firepower	C4I	Critical Thresholds

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Table of Contents

1. Introduction 1
2. Requirements Analysis 2
3. Mission Analysis 3
4. Concepts Developed 8
4.1 Technical Approach 8
4.2 Standard Propulsion System 9
4.3 Hybrid Electric Drives 13
4.3.1 Hybrid Electric Concepts 13
4.3.2 Hybrid Electric Preferred Concepts 15
4.3.3 Hybrid Electric Subsystem Component Sizing 16
4.3.4 Hybrid Electric Subsystem Technologies 17
4.3.5 Modeling and Simulation 21
4.4 Survivability, Firepower, C4I 22
5. System Trade Studies 23
6. Vehicle Weight Analysis 35
6.1 Overview 35
6.2 Approach 35
6.3 Analysis and Discussion 36

Preceding Pages Blank

2

Figures

Figure 1-1.	RST-V Concept Study Overview	2
Figure 2-1.	Key Capabilities & Critical Thresholds	3
Figure 4-1.	Technical Approach Overview	9
Figure 4-2.	Diesel Propulsion System & Drive Train Block Diagram	10
Figure 4-3.	Maximum Engine Power (HP) vs. Gross Vehicle Weight (GVW)	11
Figure 4-4.	Required Engine Power vs. Vehicle Speed	12
Figure 4-5.	Predicted Maximum Speed (Hard Dry Surface)	12
Figure 4-6.	Effects of Tire Inflation on Mobility	13
Figure 4-7.	Hybrid Electric Vehicle Candidate Concepts	14
Figure 4-8.	Specific Energy Density of Various Fuels	19
Figure 4-9.	Sample HECV Tool Box Hybrid System Model	22
Figure 5-1.	VCI vs. Tire Deflection Ratio	25
Figure 5-2.	RST Vehicle Concept Layout	27
Figure 5-3.	RST Vehicle Cross Section	28
Figure 5-4.	RST Vehicle Perpendicular Cross Section	28
Figure 5-5.	Distance Between Tires vs. Wheel Base and Wheel Track	29
Figure 5-6.	RST Vehicle Side Slope Perspective	30
Figure 5-7.	Point of Incipient Roll	30
Figure 5-8.	Track Width vs. Cornering Stability	31
Figure 5-9.	RST Concept Vehicle with Standard Propulsion System	32
Figure 5-10.	RST Hybrid Electric Drive Vehicle Concept Layout	33
Figure 5-11.	Hybrid Electric Drive System - Longitudinal Cross Section	33
Figure 5-12.	Hybrid Electric Drive System - Perpendicular Cross Section	34
Figure 5-13.	RST Concept Vehicle with Hybrid Electric Drive System	34
Figure 6-1.	Suggested Vehicle Weight Categories	36

Tables

Table 3-1.	Mission/Vehicle Characteristics Summary	4
Table 3-2.	Capabilities/Features Comparison by Mission Area	6
Table 3-3.	Critical Parameters Survey Results	8
Table 4-1.	Hybrid Electric Drive Concepts Advantages/Disadvantages	16
Table 4-2.	Hybrid Electric Subsystem Component Power Requirements	17
Table 4-3.	Energy Storage Comparison	20
Table 5-1.	Tracked vs. Wheeled Qualitative Comparison	24
Table 5-2.	Tracked vs. Wheeled VCI Comparison	25
Table 6-1.	Vehicle Weight Summary Example	37
Table 6-2.	Vehicle Armor Calculations	38

Appendixes

A.	RST-V System/Segment Specification Comments	A-1
B.	Critical Parameters Matrix Comments	B-1
C.	User Topics	C-1
D.	Diesel Engine Survey	D-1
E.	General Engine Survey	E-1
F.	Propulsion System Calculations	F-1
G.	Technology Tree for Light Strike/Reconnaissance Vehicles	G-1
H.	Survivability Survey Results	H-1
I.	Firepower Survey Results	I-1
J.	VCI Comparison - Tracks vs. Wheels	J-1
K.	VCI Calculations	K-1
L.	Initial NRMM Results	L-1
M.	Suspension/Engine Relationships	M-1
N.	Wheel Base Assessment	N-1
O.	RST-V Variants	O-1
P.	Detailed Vehicle Weight Breakdown	P-1

4

1. Introduction

Although Lockheed Martin Defense Systems (LMDS) has been acquired by the General Dynamics Corporation, this report continues to use LMDS as our company name rather than our new name which is General Dynamics Defense Systems (GDDS). This will be necessary until our Reconnaissance Surveillance Targeting - Vehicle (RST-V) study contract is officially transferred to General Dynamics. This official transfer (contract novation) is expected to occur in February 1997.

This report is considered to be an interim report for the RST-V Study Contract. A final technical report is to be provided in May 1997 upon completing this study contract. The final technical report will include the results described within this report as well as the progress made between now and the end of contract.

The basic top level objectives of the RST-V Study are to:

- Identify concepts, architectures, and technologies supportive of the RST-V System/Segment Specification (Draft, Revision 03, 26 March 1996).
- Identify those currently defined requirements that are not considered to be realizable with technologies that are either available now or will be available for effective use within the RST-V Advanced Technology Demonstrator (ATD) which is scheduled for fabrication and initial testing in FY 1999.
- Provide definition and availability estimates for technologies supportive of RST-V Specification requirements. Technology availability will be categorized into three time frames: Can be built today or is relatively low risk for RST-V ATD; Can support RST-V ATD upgrades (3-5 years out); Can only support developments beyond 5 years out.

Our basic approach to meeting RST-V Study objectives is summarized in Figure 1-1 and includes:

- Assessing information from a number of related activities and source documents.
- Analyzing user missions and identifying vehicle capabilities supportive of these missions.
- Formulating and selecting (through trade-offs) preferred concepts at the subsystem and system level.
- Providing comparisons of the performance capabilities of the preferred concepts to the current RST-V Specification requirements and proposing requirements changes as appropriate. Primary focus is to identify performance requirements and associated technologies necessary to realize capability improvements beyond HTMMP, AEDT, and JTEV as well as being suitable to support the FY 98 RST-V ATD startup.
- Characterizing and documenting preferred concepts.

This report summarizes RST-V Study progress to date and focuses on the following topics which were suggested at the RST-V Kickoff Presentation held April 10, 1996.

- Requirements Analysis
- Mission Analysis
- Concepts Developed
- System Trade Studies
- Vehicle Weight Analysis

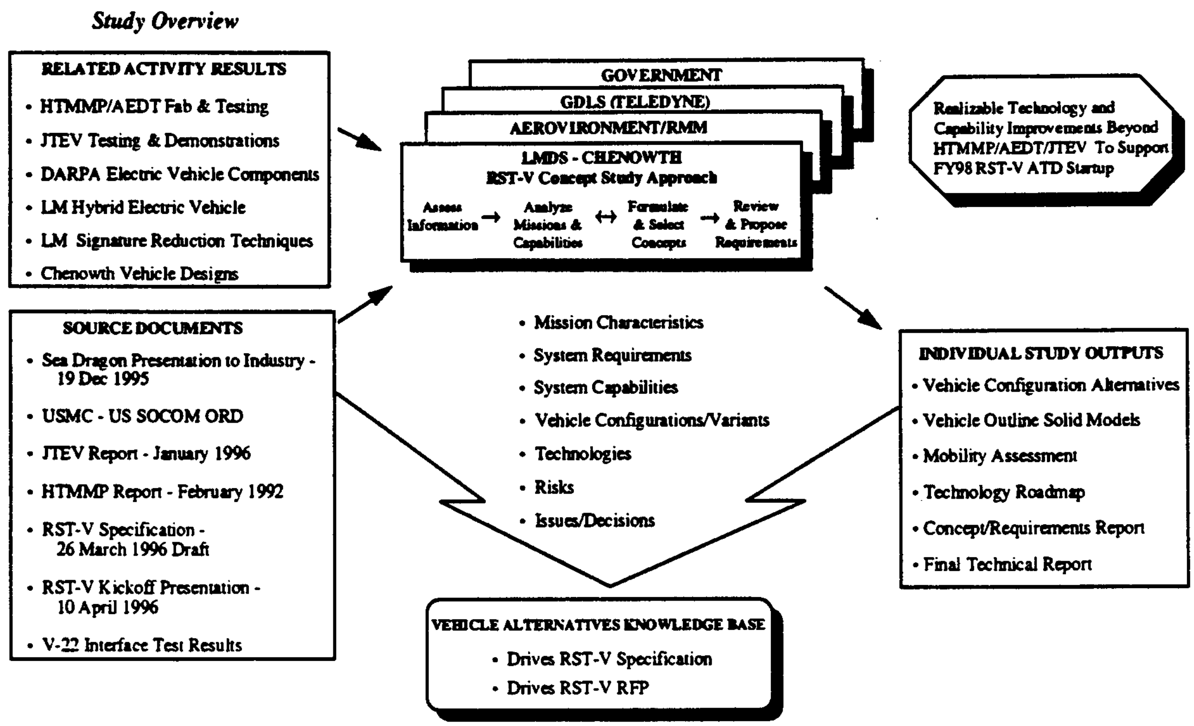


Figure 1-1. RST-V Concept Study Overview

2. Requirements Analysis

Requirements associated with the source documents and some of the related activity results listed in Figure 1-1 were assessed to determine the key capabilities and critical thresholds that new RST-V vehicle and subsystem concepts should support. An overview of these capabilities and thresholds is shown in Figure 2-1. Specific performance requirements are primarily documented in the RST-V Specification (26 March 1996) draft. As subsystem and vehicle level concepts are defined and traded off, their performance is compared to required performance thresholds and concepts are modified or specification changes are recommended as appropriate. In some cases, requirements are relative to performance achieved to date by a related activity. For instance, the RST-V Kickoff Presentation recommended performance beyond HTMMP, AEDT, and JTEV. Therefore, test results of these related activities have been reviewed to ensure concepts considered have estimated performance in excess of these already evaluated test beds.

As this study defines concepts, comments to the RST-V Specification are generated. Comments identified to date are contained in Appendix A and include both performance and document organizational comments. A summary of current findings follows. Final comments to the specification are planned to be issued near the end of the study and will include suggestions for changing performance parameter values based on findings from the design and integration phase of this study.

- Specification is relatively well structured.
- Partitioning performance characteristics by major subsystem is a good idea.

- Suggest RST-V work breakdown structure be updated to be consistent with major subsystem partitions.
- Qualitative statements (minimize, easily, fuel efficient) should be eliminated or quantified wherever possible.
- Paragraphs should be structured so that each numbered paragraph only contains a single requirement. This leads to a clearer requirement set and improves traceability between requirements, validation methods, and associated test plans and procedures.

Key Capabilities (1)

- **Weight**
  - GVW
  - Curb
  - Payload
- **Mobility**
  - Speed
    - Forward*
    - Dash (Top*)
    - Acceleration*
  - Tractive Effort*
    - Mobility Rating (%NoGo*)
    - Terrains
  - Obstacles
    - Longitudinal Slopes*
    - Side Slopes*
    - Vertical Step
    - Fording
  - Maneuverability
    - Turning (Dynamic)
    - Turning (Static)
    - Vehicle Cone Index
  - Interfaces
    - Approach Angle
    - Departure Angle
    - Ground Clearance
- **Mobility (Continued)**
  - Ride Quality*
  - Range
- **Survivability**
  - Acquisition Avoidance
  - Penetration Avoidance
  - Kill Avoidance
    - NBC
- **Firepower (2)**
- **C⁴I (2)**
- **Transportability**
  - Air Transportation
    - Width
    - Height
- **Flexibility & Expansion**
  - Modular Subsystems & Components
    - Structural & Connect/Disconnect Features
  - Growth
- **Logistics**
  - Operations & Support Cost
  - Average Unit Rollaway Cost

(1) Initial Focus for Establishing Common System Baseline Concept
(2) No New Concepts Being Developed (Assessed to Establish Space, Weight, & Power Claims)
* "Critical Factors" From Kickoff Presentation

Critical Thresholds/Features

-

Weight	GVW	Curb	Payload
USMC	6500	5000	1500
SOCOM	8000	5000	3000

- **Speed**
  - Acceleration*
  - Top Speed*
  - Ride Quality*
- **Trafficability - % NoGo***
- **Range**
  - USMC 300 Miles
  - SOCOM 450 Miles
- **> 8 Miles Silent Operation**
- **Transport - Tactical***
- **V-22 Internally Transportable**
- **Mobility**
  - Minimum ≥ HMMWV
  - Objective ≥ Maneuver Force
- **Obstacles**
  - Tractive Effort*
  - Slope Operations*
- **Weapons Up in 15 Seconds**
- **Hybrid Electric Drive**
- **25 kw Excess Auxiliary Power**
- **4 Variants (Personnel, Weapons, Sensors, Litter Carrier)**

Figure 2-1. Key Capabilities & Critical Thresholds

3. Mission Analysis

A variety of missions have been assessed and the essential vehicle characteristics of each have been identified. Characteristics include payload, weapons, sensors, communications, and range as well as the relative importance of stealth, mobility, firepower and protection. Missions included USMC Combat Missions for Light Vehicle Operations (Amphibious Raid, TRAP, Airfield Seizure, Recon/Surveillance, Limited Objective Attack), Special Operations Missions (Recon-Special Ops, RST-Short Duration, RST-Scout Mission, RST-Small Unit Ops), Operational Maneuvers from the Sea (Troop Carrier, Fire Support, Command and Control, Logistic Support, Medical Evacuation, Deep Recon and Targeting), and Operations Other than War (Rescue Non-combatants, Show of Force, Peacekeeping). A summary of mission/vehicle characteristics is shown in Table 3-1.

Table 3-1. Mission/Vehicle Characteristics Summary

MISSION	PAYLOAD	WEAPONS	SENSORS & COMMS	RANGE OFF ROAD	RANGE ON ROAD	OTHER CHARACTERISTICS
ESTABLISHED USMC COMBAT MISSIONS FOR LIGHT VEHICLE OPERATIONS						
Amphibious Raid	3 Crew 2500 lbs	MK19 /M2 M60/M240	TTS, NVG Comms	250 mi	100 mi	Stealth, Dash Speed, Firepower
TRAP	3 Crew 1500 lbs	MK19 / M2 M60/M240	TTS, NVG Comms	250 mi		Stealth, Offroad Mobility
Airfield Seizure	3 Crew 2000 lbs	MK19 / M2 M60/M240	TTS, NVG Comms	150 mi		Stealth, Dash Speed, Firepower
Recon / Surveillance	3 Crew 1500 lbs	MK19 / M2 M60/M240	TTS, NVG Comms	100 mi		Stealth, Dash Speed, Offroad Mobility
Limited Objective Attack	3 Crew 2500 lbs	MK19 / M2 M60/M240	TTS, NVG Comms	250 mi	100 mi	Stealth, Dash Speed, Firepower
SPECIAL OPERATIONS MISSIONS (compiled by NSWC Carderock)						
Recon, Special Ops	3/4 Crew 2000 lbs	MK19 / M2 M60/M240	TTS, NVG Comms	350 mi	100 mi	Stealth, Mobility, Firepower, Endurance
RST: Short Duration	3/4 Crew 2000 lbs	MK19 / M2 M60/M240	TTS, NVG Comms	100 mi	50 mi	Stealth, Mobility, Firepower, Dash Speed
RST: Scout Mission	3/4 Crew 2000 lbs	MK19 / M2 M60/M240	TTS, NVG Comms	300 mi	100 mi	Stealth, Mobility, Firepower, Dash Speed
RST: Small Unit Ops	3/4 Crew 2000 lbs	MK19 / M2 M60/M240	TTS, NVG Comms	300 mi	20 mi	Stealth, Mobility, Firepower, Endurance
OPERATIONAL MANEUVER FROM THE SEA - GROUND MANEUVER WARFARE						
Troop Carrier	2 Crew 4 Infantry	M60/M240 Pers Wpns	NVG Comms	150 mi	100 mi	Stealth, Mobility, Dash Speed
Fire Support	3 Crew 2500 lbs	MK19 / M2 Mortars	TTS, NVG Comms	150 mi	100 mi	Stealth, Mobility, Dash Speed
Command and Control	3 Crew 2500 lbs	MK19 / M2 M60/M240	TTS, NVG Comms	150 mi	100 mi	Stealth, Mobility, Dash Speed
Logistic Support	2 Crew 3000 lbs	M60/M240 Pers Wpns	TTS, NVG Comms	200 mi	100 mi	Stealth, Mobility, Dash Speed
Medical Evacuation	2 Crew, 4 Litters	M60/M240 Pers Wpns	TTS, NVG Comms	150 mi	100 mi	Stealth, Mobility, Protection, Dash Speed
Deep Recon & Targeting	3 Crew 3000 lbs	MK19 / M2 M60/M240	TTS, NVG Comms	200 mi		Stealth, Mobility, Dash Speed, Endurance
OPERATIONS OTHER THAN WAR						
Rescue Non-Combatants	2/3 Crew 1500 lbs	MK19 / M2 M60/M240	TTS, NVG Comms	100 mi	250 mi	Mobility, Dash Speed, Firepower, Protection
Show of Force	3 Crew 2500 lbs	MK19 / M2 M60/M240	TTS, NVG Comms	100 mi	250 mi	Deterrence: Speed Firepower, Protection
Peacekeeping	3 Crew 2500 lbs	MK19 / M2 M60/M240	TTS, NVG Comms	100 mi	250 mi	Stealth, Dash Speed, Firepower, Protection

These missions and their essential characteristics were then grouped into four mission areas: Reconnaissance Surveillance Targeting (RST), Strike, Personnel, and Litters/Logistics as shown in Table 3-2. The essential capabilities/features for each mission area were defined across the major subsystems of mobility, firepower, survivability, and C4I (Command, Control, Communications, Computer and Intelligence). Qualitative rankings of mobility capabilities were established across the mission areas and all capabilities were divided into three categories: Capabilities common to all mission areas (Green table entries); capabilities unique to one mission area (Red table entries); and capabilities common to two or three mission areas (Black table entries).

8

As subsystem and vehicle level tradeoffs are made, these mission/capability categorizations will be used to support initial vehicle configuration selections. In addition to the above mission/capabilities categorizations, our project team has reviewed, discussed and filled out a critical parameters matrix provided by Carderock at the RST-V Concept Study In-process Review #1. Participants included systems, safety, and field support engineers. Survey results for the four functional categories of lethality, supportability, survivability, and mobility are shown in Table 3-3. A summary of our findings follows and specific findings are contained in Appendix B.

- Survey is valuable (filling it out forces priorities to be established).
- Survey participants should be interviewed to ensure rationale for priorities is understood.
- Participant's background and rationale should be documented.
- Present survey form (general in nature) appropriate prior to definition of mission specific vehicle and subsystem concepts.
- Separate survey forms are recommended (each tailored to particular mission area).
- Separate forms, tailored to each mission area of interest could provide more accurate survey conclusions.
- Minimum set of top level filters (mandatory requirements) will help focus developer and could reduce development costs if other requirements are not too stringent or are defined as goals.
- Present method of scoring causes participants to spend too much time dealing with math (suggest rounded percentages).

A more detailed user perspective is needed before making final configuration selections during the design and integration phase of this study. It is planned to obtain this perspective by interviewing ground weapons personnel at Quantico. Topics to be discussed are contained in Appendix C.

Table 3-2. Capabilities/Features Comparison by Mission Area (1 of 2)

Mission Area	LCC .4 (7)	Mobility (I) .3 (7)	Firepower .2 (7)	Survivability .1 (7)	C4I 0 (7)	Payload
RST: Recon/Surveillance Recon/Special Ops RSTA: Short Duration RSTA: Scout Mission RSTA: Small Unit Ops Deep Recon & Targeting		Dash Speed is important: 70 mph [2] Central Tire Inflation Sustained Low Speed is necessary, 3 mph @ 3 hrs [4] Forward Speed is very important [3] %NoGo is very important [3] Tractive Effort is important [2] Slope Stability is very important [3] Ride Quality is very important [3] Semi-Active or Active Suspension?	Target Acquisition Capabilities: Acoustic Sensor Seismic Sensor? RF Target Acquisition Equipment Low Light Level TV Visible Video FLIR? Radiac Set? Vehicle ID System Laser Rangefinder Driver's Thermal Viewer? 10 Meter Mast? Sight Head w/Azi Drive & Stab Primary: MK19 , M2, Javelin or TOW [3] -and- Secondary: M60 or M240G	**Acquisition Avoidance:** Signature Management Acoustic Engine Suppression Thermal Engine Suppression IR False Target Generator? RF Jammer? Ventilated Face Piece Micro Climate Cooling? **Hit Avoidance:** Laser Warning Receiver Radar Warning Receiver Dash Speed **Penetration Avoidance:** Protection against mines (floors & wheel wells) **Kill Avoidance:** NBC Standoff Detector Chemical Agent Detector	Pos Nav System Sincgars (2 Radio) CVC2 Processor? Control & Display Panels EPLRS TAC Satellite? Low Freq Long Distance?	3 -4 man crew 2000 - 3000 lb payload 100 - 350 mi offroad range 0 - 100 mi onroad range
Strike: Amphibious Raid TRAP (2) Airfield Seizure Limited Obj. Attack Fire Support Show of Force Peacekeeping		Dash Speed is necessary; 70 mph [4] Central Tire Inflation Sustained Low Speed is not important [0] Forward Speed is very important [3] %NoGo very important [3] Tractive Effort very Important [3] Slope Stability very important [3] Ride Quality is important [2] Semi-Active or Active Suspension?	Target Acquisition Capabilities: Acoustic Sensor Seismic Sensor? RF Target Acquisition Equipment Low Light Level TV Visible Video FLIR? Radiac Set? Vehicle ID System Laser Rangefinder Driver's Thermal Viewer 10 Meter Mast? Sight Head w/Azi Drive & Stab Primary: MK19 , M2, Javelin or TOW or mortar [4] (3) -and- Secondary: M60 or M240G	**Acquisition Avoidance:** Signature Management Acoustic Engine Suppression Thermal Engine Suppression IR False Target Generator? RF Jammer? Ventilated Face Piece Micro Climate Cooling? **Hit Avoidance:** Laser Warning Receiver Radar Warning Receiver Critical dash speed **Penetration Avoidance:** Configurable Armor Protection against mines (floors & wheel wells) **Kill Avoidance:** NBC Standoff Detector Chemical Agent Detector	Pos Nav System Sincgars (2 Radio) CVC2 Processor? Control & Display Panels EPLRS TAC Satellite? Low Freq Long Distance?	3 man crew 1500 - 2500 lb payload 100 - 250 mi offroad range 100 - 250 mi onroad range

Table 3-2. Capabilities/Features Comparison by Mission Area (2 of 2)

Mission Area	LCC .4 (7)	Mobility (1) .3 (7)	Firepower .2 (7)	Survivability .1 (7)	C4I 0 (7)	Payload
Personnel: Troop Carrier Rescue Non-Combatants		Dash Speed is very important [3] Central Tire Inflation Sustained Low Speed is not important [0] Forward Speed is very important [3] % NoGo is very important [3] Tractive Effort is important [2] Slope Stability is important [2] Ride Quality is very important [3]	Secondary: M 60 or M 240G No Primary Required Limited Target Acquisition Equipment: Vehicle ID System	Acquisition Avoidance: Signature Management? Acoustic Engine Suppression? Thermal Engine Suppression IR False Target Generator? Hit Avoidance: N/R Penetration Avoidance: Protection against mines (floors & wheel wells) Kill Avoidance: NBC Standoff Detector Chemical Agent Detector	Control & Display Panels?	2 / 3 man crew / 4 infantry 1500 lb payload 100 - 150 mi offroad range 100 - 250 mi onroad range
Litters / Logistics: Logistic Support Medical Evacuation		Dash Speed is important [2] Central Tire Inflation Sustained Low Speed is not important [0] Forward Speed is very important [3] % NoGo is importanct [2] Tractive Effort has minimal importance [1] Slope Stability has minimal importance [1] Ride Quality is very important [3]	Secondary: M 60 or M 240G No Primary Required Limited Target Acquisition Equipment: Vehicle ID System	Acquisition Avoidance: Signature Management? Acoustic Engine Suppression? Thermal Engine Suppression IR False Target Generator? Hit Avoidance: N/R Penetration Avoidance: Protection against mines (floors & wheel wells) Kill Avoidance: NBC Standoff Detector Chemical Agent Detector	Control & Display Panels?	2 man crew 4 litters 3000 lb payload 150 - 200 mi offroad range 100 mi onroad range

Notes:
(1). Mobility requirements are ranked in order of importance. These rankings are shown by a number in brackets ([4] Mandatory/Critical; [3] High Value/Very Important; [2] Medium Value/Moderately Important; [1] Limited Value; [0] No Value).
(2). TRAP requires the capability to pick up and transport troops (on the order of 1 - 3).
(3). Javelin, TOW or Mortar weapons are for Indirect Strike missions.
(4). A question mark following an entry means that the item's need is unknown.
(5). The Command & Control Mission is unique and doesn't fit into one of the four main mission areas.
(6). All mission areas require personal heaters.
(7). These values are the current weightings from the draft RSSV Specification.
Color coding: Green for common attributes, red for unique attributes, and black for attributes that support two or three mission areas.

Table 3-3. Critical Parameters Survey Results

LSV

Function	Survey Participant							Average Value
	Systems Engr (1)	Systems Engr (1)	Systems Engr (1)	Safety Engr (2)	Field Engr (3)	Systems Engr (4)	User	
Lethality	.40	.35	.30	.40	.30	-		.35
Supportability	.20	.10	.20	.20	.20	-		.18
Survivability	.10	.25	.25	.10	.20	-		.18
Mobility	.30	.30	.25	.30	.30	-		.29

RSTA-V

Function	Survey Participant							Average Value
	Systems Engr (1)	Systems Engr (1)	Systems Engr (1)	Safety Engr (2)	Field Engr (3)	Systems Engr (4)	User	
Lethality	.10	.25	.20	.20	.15	-		.18
Supportability	.20	.15	.20	.20	.25	-		.20
Survivability	.40	.30	.30	.40	.25	-		.33
Mobility	.30	.30	.30	.20	.35	-		.29

General

Function	Survey Participant							Average Value
	Systems Engr (1)	Systems Engr (1)	Systems Engr (1)	Safety Engr (2)	Field Engr (3)	Systems Engr (4)	User	
Lethality	.20	.20	.25	.35	-	.14		.228
Supportability	.30	.10	.20	.15	-	.08		.166
Survivability	.20	.30	.25	.20	-	.18		.226
Mobility	.30	.40	.30	.30	-	.60		.38

(1) Land Combat Systems Engineering
(2) Safety Engineering
(3) Field Support Engineering
(4) Mission/Vehicle Capabilities Analysis

4. Concepts Developed

4.1 Technical Approach

An overview of our technical approach is shown in Figure 4-1. The Key initial tradeoff is between tracked and wheeled vehicle topologies followed by standard drive train and initial vehicle level solid modeling and associated assessments. These trades and selections are driven by key RST-V specification requirements, mission analysis results, earlier described related activity test results, as well as a survey of today's technologies. Starting with a relatively well known standard propulsion system allows a solid basis of essential constraints and performance characteristics to be established before advanced propulsion (including hybrid electric drives and active suspension) systems are concepted and assessed both at the subsystem and vehicle levels. The NATO Reference Mobility Model (NRMM) will be applied to confirm standard propulsion system assessments already performed, as well as the advanced concepts being assessed during the design and integration phase of this study. In addition, the Hybrid Electric Combat Vehicle (HECV) Software is being applied to evaluate alternate hybrid electric drive configurations. A

survey of advanced technologies in the areas of survivability, firepower and C4I is also being conducted and the preferred technologies will be selected based upon an assessment of their performance against requirements. Selected technologies will also be incorporated within vehicle level solid models to assess space and weight claim impacts prior to defining preferred concepts. Results to date are covered in the following paragraphs.

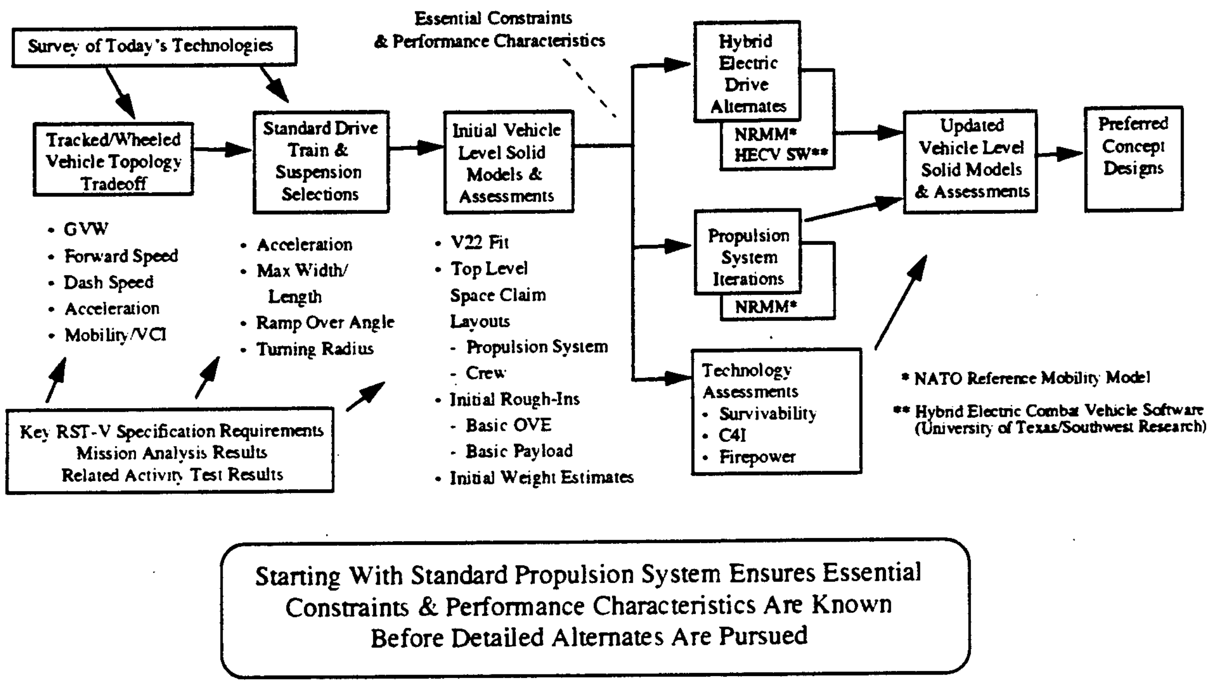


Figure 4-1. Technical Approach Overview

4.2 Standard Propulsion System

The selection of standard propulsion system components was driven primarily by speed and mobility requirements. Starting with the ground contacting elements, it was determined that in order to meet the mobility and VCI requirements, a minimum of a 4x4 all wheel drive (AWD) configuration with 33" diameter tires would be required. At an assumed 95% tire radius, the estimated "static load driving radius" equals 1.31 feet and the tire's revolutions per mile is 611. Power to the wheels would be obtained by a conventional four wheel drive approach as shown in Figure 4-2.

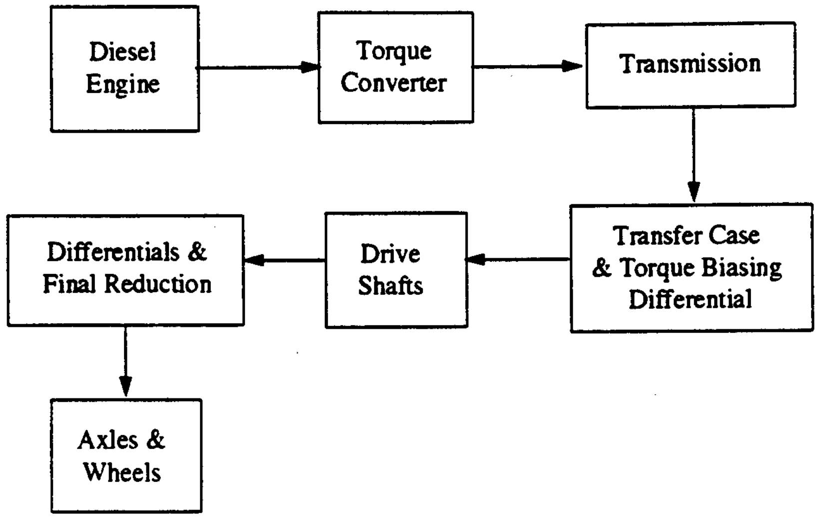


Figure 4-2. Diesel Propulsion System & Drive Train Block Diagram

Sizing of the remaining drivetrain and propulsion system components was calculated with the following assumptions:

- curb weight = 3500 lb (max GVW = 6500 lb)
- torque is biased to equal the weight distribution under all circumstances
- frontal area = 80% (W x H) = 60" x 66" X 0.8 / 144 = 22 ft^2
- overall drivetrain efficiency (flywheel to tire patch) = 80%
- drag coefficient = 0.75 (note passenger cars range from 0.35 - 0.45, trucks = 0.7 and trailers = 1.2)
- coefficient of rolling resistance:

  f_{sand} = 0.26

  $f_{med\ soil}$ = 0.10

  $f_{pavement}$ = 0.03

With the assumed gross vehicle weight, drag coefficient and rolling resistance, it was possible to estimate the required power to meet the acceleration requirements. This was found to be 168 hp to meet 0 - 30 mph in 6 seconds and 211 hp to meet 0 - 60 mph in 15 seconds. This power, together with the choice of being automatic, limits the choice of transmissions to either the GM 4L80E (a 4 speed automatic with overdrive) or the Mercedes Benz (5 speed automatic with overdrive). Each costs about $2500 and weighs about 250 pounds. The GM was chosen over the Mercedes as it is currently being used in the HMMWV and offers better supportability in the US. It has the following gear ratios: first = 2.48:1, second = 1.48:1, third = 1.0:1 and fourth = 0.75:1. The remaining drivetrain ratios were assumed to be 4.56:1 as a final reduction, 1:1 in the transfer case and 1.9:1 in the torque converter at lockup conditions. The 4.56:1 final reduction is typically a 41 tooth ring gear meshed with a 9 tooth pinion gear at each front and rear axle. A 1:1 transfer case torque biasing capability is common and available through sources such as Borg-Warner, Dana and New Venture Gear. The torque converter is a hydro-kinetic unit with a

14

maximum multiplication of 1.9 at start-up conditions. This drops to 1:1 (no multiplication) typically around second or third gear for minimal losses. The acceleration requirement was found to be the dominant driver in terms of propulsion system sizing and is shown versus GVW in Figure 4-3. The remaining speed and mobility requirements were found to result in the following power demands:

- Drawbar Pull	197 ft - lb
- 75 mph Top Speed	109 hp (81 kW) @ 2613 rpm
- Start on 60% Slope	277 ft-lb
- Climb 5% at 40 mph	139 hp (103 kW)
- Tow equal up 40% slope	6.42 mph @ 139 hp

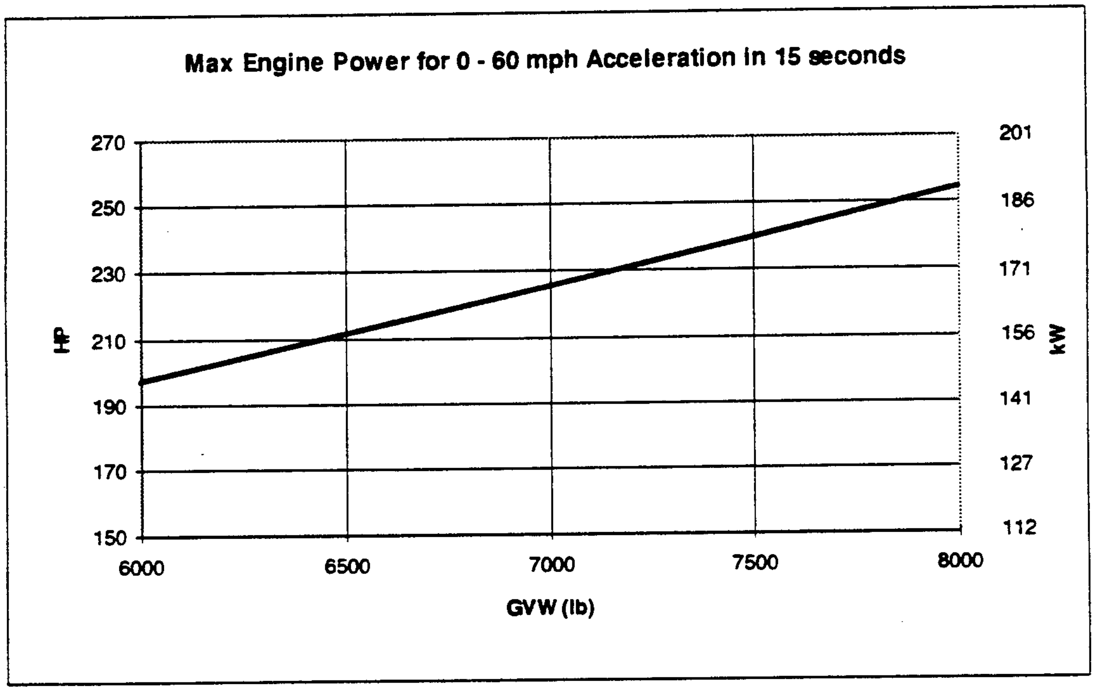


Figure 4-3. Maximum Engine Power (HP) vs. Gross Vehicle Weight (GVW)

An industry survey of diesel engines is included in Appendix D. From this listing, a preferred subset has been identified and is included in Appendix E.

The effects of efficiency on maximum vehicle speed is shown in Figure 4-4. From this it can be shown that with the above mentioned assumptions, a conventional propulsion system would require about 109 hp to achieve 75 mph top speed with 80% efficiency and at a gross vehicle weight of 6,500 lb while a more efficient propulsion system, like one might expect with a hybrid-electric system, the required power is reduced to 89 hp. Similarly, at a GVW of 8,000 lb, the required powers are 120 and 101 hp respectively.

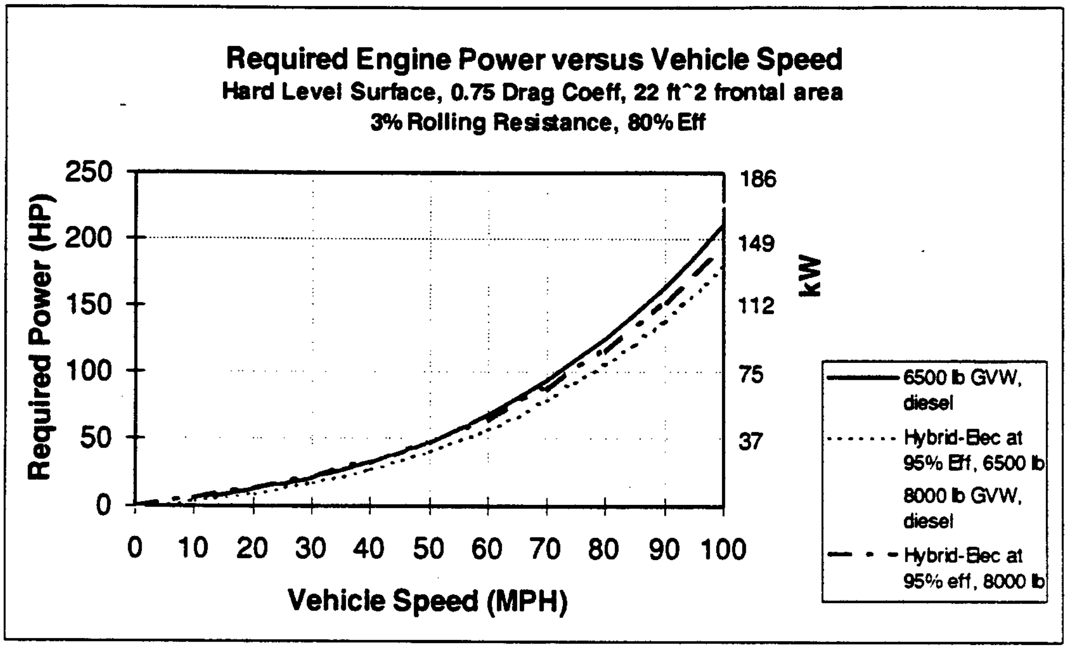


Figure 4-4. Required Engine Power vs. Vehicle Speed

In Figure 4-5, maximum vehicle speed is shown as a function of GVW for three given engine power sizes. This data is based on hard level driving as might be experienced over primary roads and superhighways.

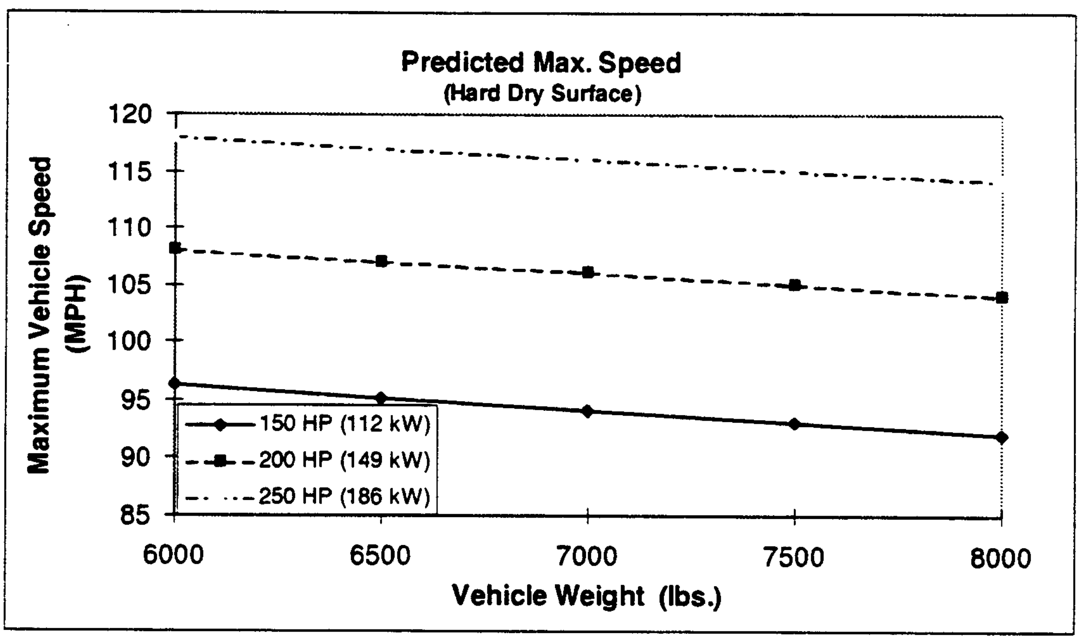


Figure 4-5. Predicted Maximum Speed (Hard Dry Surface)

Once off-road conditions are encountered, the maximum vehicle speeds must be reduced for various reasons such as driver comfort and safety. In order to be able to drive quickly on adverse surfaces, it may be necessary to employ a central tire inflation system (CTIS). The effects of

varying the tire pressure on vehicle speed are shown in Figure 4-6. This shows that a 6500 lb vehicle (GVW) at a typical tire pressure of 24 psi could travel at highway speeds with a tire deflection ratio of 10 - 20%. The VCI in this case would be about 22. CTIS is one alternative to enable the driver to travel on soils with a cone index of less than 22. For example, in the 4x4 configuration shown in Figure 4-6, the VCI can be lowered to about 17 by lowering the tire pressure to 15 psi which would reduce the deflection ratio to about 35% - 40% which is the maximum lower limit for which most tires are rated. This would reduce the vehicle's speed, perhaps to 5 - 10 mph, but would allow for continued driveability. VCI is covered in detail in paragraph 5. Of course, the tire's pressure can be manually lowered in pressure but this takes time and the driver must stop the vehicle to do so. CTIS allows the driver to adjust tire pressures up or down while on the run. The amount of time required to inflate the tires is a function of the size of the on board air compressor. One drawback of CTIS is that it increases the "unsprung" weight due to the rotary pneumatic joints required at each hub. Most modern CTI systems have an electronic controller which enables the operator to select desired pressure within the recommended limits from the tire's manufacturer.

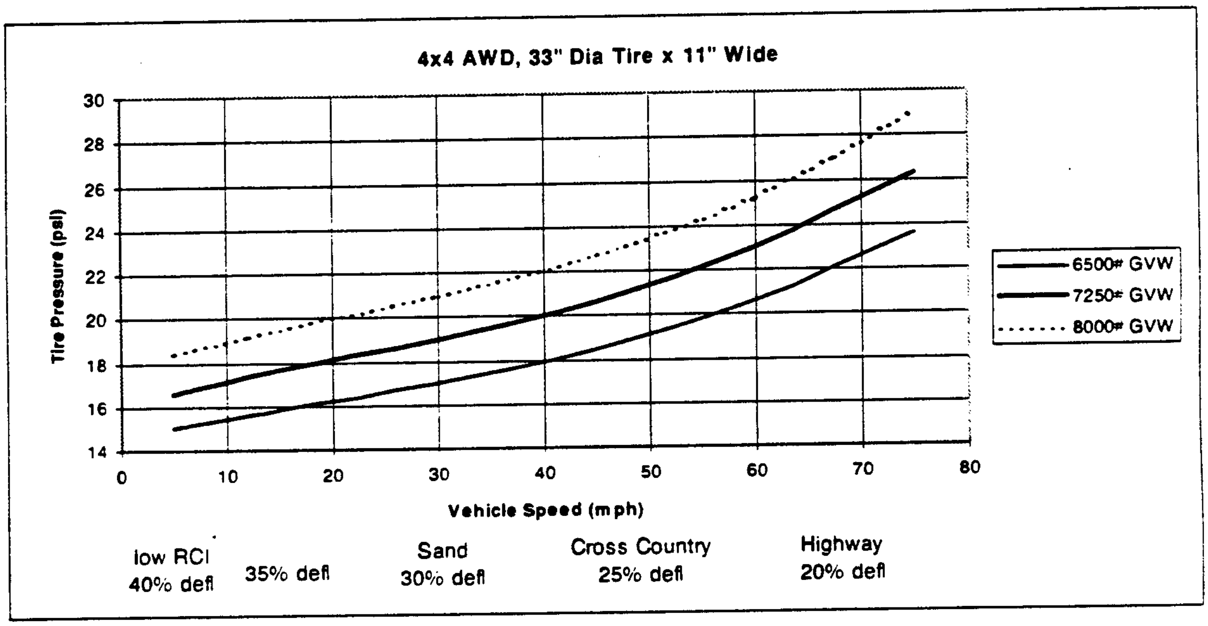


Figure 4-6 Effects of Tire Inflation on Mobility

Calculations used to determine performance characteristics necessary to achieve maximum speed, starting on 60% slope, climbing a 5% grade at 40 mph, towing self and equal weight up 40% slope, as well as acceleration requirements are contained in Appendix F.

4.3 Hybrid Electric Drives

4.3.1 Hybrid Electric Concepts

Four hybrid electric drive concepts have been considered for the RST-V application. All concepts provide both the ability to run directly off of an electric power generating prime mover as well as off stored energy required for stealth mode. These concepts are shown in Figure 4-7.

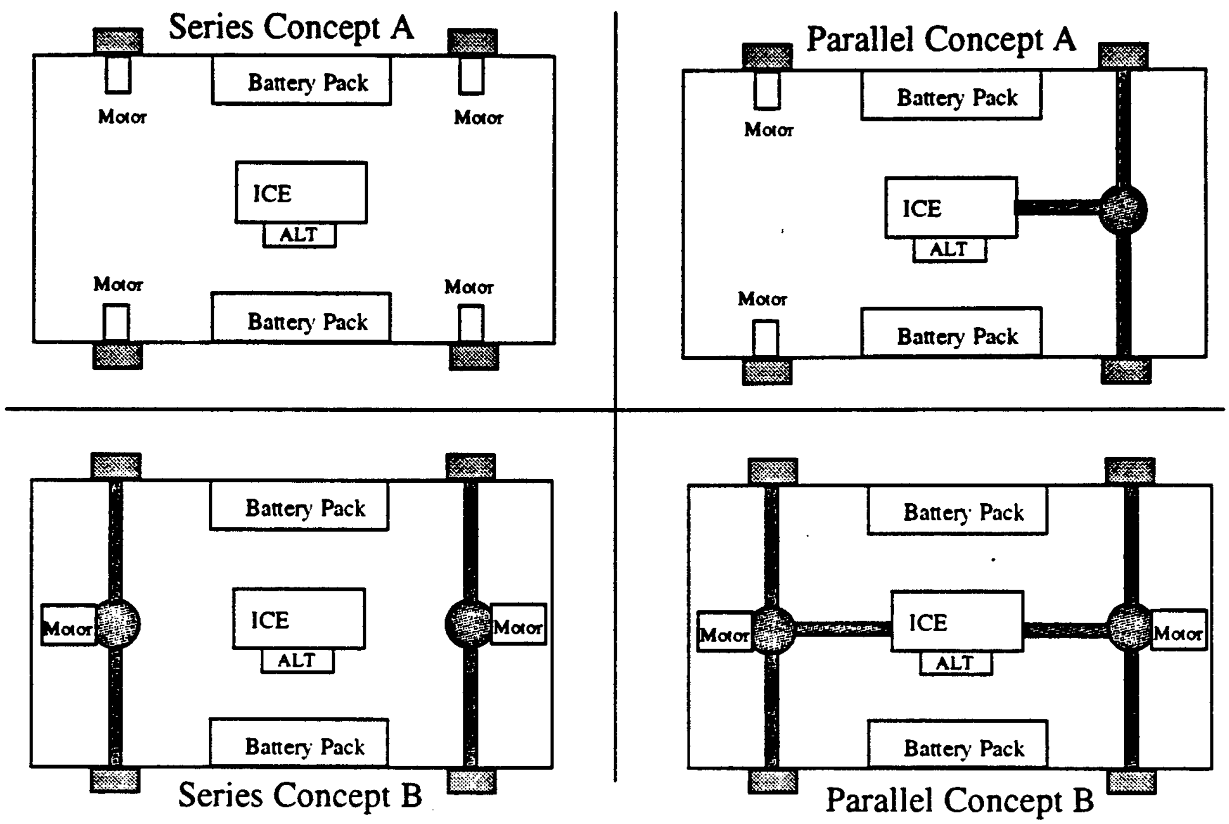


Figure 4-7. Hybrid Electric Vehicle Candidate Concepts

Series Concept A

This series concept utilizes an individual drive motor for each wheel with an APU sized for the average power demand. This configuration allows individual control of each wheel rate as well as torque. No mechanical linkage from the prime mover is used which allows the prime mover to be operated at its most efficient operating point. Stealth (or all electric mode) utilizes energy stored in batteries, flywheels, ultracapacitors, etc. Motors are sized for continuous power. Peak power is approximately 4 times continuous rating. Control of each wheel's speed is done by computer algorithm. Wheel speed during turning must be controlled fairly accurately to prevent counter torques. Wheel rate control allows traction and skid control. Rate control also prevents overspeeding/underspeeding of the wheels if the vehicle should leave the ground and avoids the counter torques responsible for sheering driveshafts on landing. The energy storage medium (typically batteries) is sized for prolonged stealth operation (20 miles). All four wheels are available for regenerative braking.

Series Concept B

This configuration is similar to Concept A except for the use of mechanical differentials for ease of control. Individual wheel rate control is not possible with differentials. Torque control is implemented. Two motors also simplify the electronics. As in Concept A no direct mechanical connection exists between the prime mover and the wheels. The use of differentials is a significant drawback due to added weight and the tendency to lockup or skid a wheel during low speed turning.

Parallel Concept A

Parallel configurations have the ability to employ both mechanical and electrical propulsion either individually or in concert. This concept utilizes a combination of standard mechanical linkage transmission for driving the rear (or front) wheels while the front wheels are driven by electric motors. The parallel connection is via the road. This configuration takes advantage of the fact that hybrid electric drives are more efficient for urban driving due to the regeneration of energy through braking, however are actually less efficient for highway driving due to the additional energy conversion which takes place. With this configuration , the prime mover provides the continuous power for the long haul across country while the electric drives are used for hard acceleration requirements and stealth mode (electric operation only). The prime mover would be sized for slightly more than average power.

Parallel Concept B

This configuration is a fully redundant topology which uses direct mechanical linkages and transmissions to route mechanical and or electrical power to the wheels. Here the electric motors would supply additional torque on demand as well as propulsion in stealth mode. The use of differentials prevents individual wheel control and the added weight due to the redundancy is a significant drawback. Redundancy, while providing total backup also adds twice the complexity.

A summary of the salient features of each concept appears in Table 4-1.

4.3.2 Hybrid Electric Preferred Concepts

The Downselect process eliminated two (2) concepts. The preferred concepts are Series Concept A and Parallel Concept A.

Series Concept A benefits from fully independent wheel control (rate, torque and regenerative braking). The elimination of the differentials makes this possible. The four (4) motors provide full stealth mobility, drive redundancy and component placement flexibility.

Series Concept B was eliminated primarily due to limitations associated with the differentials (i.e. no rate control, skidding in turns, drivetrain stress on landings, etc.).

Parallel Concept A retains a mechanical link to the wheels to reduce fording risk while maintaining a simple separation of the electrical and mechanical system. This avoids the use of a "summing gear" to combine mechanical and electrical power. The electric motors are used as generators under normal driving. They provide the additional torque for hard acceleration and hill climbing. They provide limited stealth capability when used by themselves.

Parallel Concept B was eliminated primarily due to additional complexity, weight and volume of full mechanical redundancy.

Table 4-1. Hybrid Electric Drive Concepts Advantages/Disadvantages

HED	Advantages	Disadvantages
Series Concept A	Common Components Redundant Drive Motors Independent Wheel Torque Control Exceptional Skid Prevention Simpler Mechanical Systems Most Flexible Control System Most Flexibility for Component Placement IC Engine Sized for RMS Power Most Efficient for Stop and Go Operation	Higher Fording Risks (No Mech Drive) More complex Electrical/Control System Larger Alternator Required More Complex Electrical Motor Cooling
Series Concept B Discarded	Simple Locking Differentials Simple Control System Simplest Integration	Additional Gear/Axle Weight Higher Fording Risks (No Mech Drive) Differential Gears - Torque Control Only No Independent Traction Control
Parallel Concept A	Simple Separation of Mech./Elec Sys Electric Drive Invoked Under Hand Acceleration or Climbing High Survivability - Redundant Systems Most Efficient at Highway Speed Fording Risks Reduced Motors Can Be Used as Generators Small or No Alternator Minimum Cooling	Degraded Climb Traction in Stealth Degraded Acceleration/Top Speed in Stealth Additional Gear/Axle Weight Only Partial Regenerative Braking Differential Gears - Poor Torque Control
Parallel Concept B Discarded	Most Acceleration Torque Available Highest Survivability - Fully Redundant AWD Smallest Alternator	High Complexity (Summing Gears, Mech/Elec Systems) Most Weight Most Volume Summing Gears - Poor Torque Control Largest Battery Pack Required For Same Stealth Range

4.3.3 Hybrid Electric Subsystem Component Sizing

Development of the required capabilities for the individual hybrid electric subsystem components was derived at the top level from the following vehicle performance requirements. These performance criteria were also used for the standard propulsion system analyses discussed in paragraph 4.2.

- Drawbar Pull	0.4 TE/GVW
- Max Speed	75 mph
- Start On Slope	60%
- Climb Slope	5% at 40 mph
- Tow	Equal Weight, 40% Slope
- Acceleration	
0 to 30 mph	6 sec
0 to 60 mph	15 sec

Sizing of the Hybrid Electric drive major components was based on the vehicle level performance requirements with the following assumptions:

- The parallel configuration will have reduced performance in Stealth Mode since only two wheels are driving.
    - Slope 40%
    - Max speed 30 mph
    - Limited tow/drawbar pull
    - Limited traction
- Motors sized for maximum continuous power required to maintain maximum speed.
- Peak motor power / torque is 4 x continuous (i.e.. rated) for 60% slope and acceleration (15 sec 0-60).
- Prime power (IC engine) is sized for maximum continuous power + aux. power + losses.
- Electric range goal is 20 miles.
- 25 kw is available for auxiliary power in hybrid mode with 1 kwh reserved for auxiliary power in stealth mode. Limited auxiliary power available during heavy acceleration / hill climbing.
- Electric motor weight is 2 lbs/hp (non-liquid cooled desired).
- Single gear mesh reductions (98.5% eff.)
- Power distribution efficiency is 99%
- Electric motor efficiency is 93%

Table 4-2 lists the power requirements for the major components for each of the two candidate concepts.

Table 4-2. Hybrid Electric Subsystem Component Power Requirements

Components	Series Concept	Parallel Concept
Prime Mover/Alternator - includes propulsion and 25 kW aux	105 kW (140 Hp)	107 kW (143 Hp)
Motors (ea.) rated - Peak	16.4 kW (22 Hp) - 4 X rated (4 motors)	14 kW (19.5 Hp) - 4 X rated (2 motors)
Drive Train	15:1	30:1 (Electric)
Energy Storage	20 kwh	11 kwh
Power Electronics (peak)	310 kW	137 kW

4.3.4 Hybrid Electric Subsystem Technologies

The subsystem component sizing serves as a basis for the assessment of the appropriate technology candidates. The five main areas of focus are:

21

- Prime mover / alternator - diesel, gas turbine, fuel cells, etc.
- Motors (propulsion) - brushless technology
- Drive train - gearboxes (if any), drive shafts
- Energy storage - batteries, ultracapacitors, flywheels
- Power electronics - inverter technology, processor architecture, power management

Each of these areas is being investigated to find the leading edge technology and determine the best fit for the application. The selected technology must be available within 2 years to support the RST-V ATD program.

4.3.4.1 Prime Mover

A survey of available energy sources for prime power covered a wide variety of energy conversion technologies. Standard technologies (Diesel engines, Rotary engines and gas turbines) were the focus, however more radical technologies were also reviewed including Solar, Nuclear, and Fuel Cell technology. A synopsis follows:

- Diesel; Mature technology, high efficiency, but heavy, poor emissions, noisy.
- Rotary; High power density, moderate efficiency, but questionable emissions, seals.
- Turbine; Very high power density, low noise, multiple fuels, but high cost.
- Fuel cell; Very efficient, but - low power density, complex, fuel logistics complex.
- Solar; Free energy, but low power density, area intensive, weather dependent.
- Nuclear; High power, but dangerous, high volume, complex control.

When considering the internal combustion engines, the rotary technology has advanced in the area of emissions and seals. Rotary technology has a high power-to-weight ratio (about 0.6 hp/lb) because reciprocal motion does not have to be converted into rotary motion as done with conventional engines. Focus is being placed on the latest multi-valve, electronically controlled diesel engines, rotary engines, and small, scaleable turbines.

Of the new technologies fuel cells are the most attractive, but lack the power density (even when considering near term advances) demanded by the operational scenarios for this vehicle. Solar has the obvious limitation of no night time operation as well as weather dependence, in addition to the lack of power density. Nuclear power is dangerous, difficult to control and is scale limited with the current and near term technology considering the prime mover volumetric allocation.

The specific energy density of various fuels is shown in Figure 4-8. A quick look at the fuel options that are available today, indicates that the fuel of choice remains diesel for RST-V applications. Although hydrogen (used for fuel cells) has significantly higher energy density, it is presently not practical as a prime mover fuel since it is difficult to transport in liquid form and there are inefficiencies associated with generating hydrogen from other on-board fuels.

22

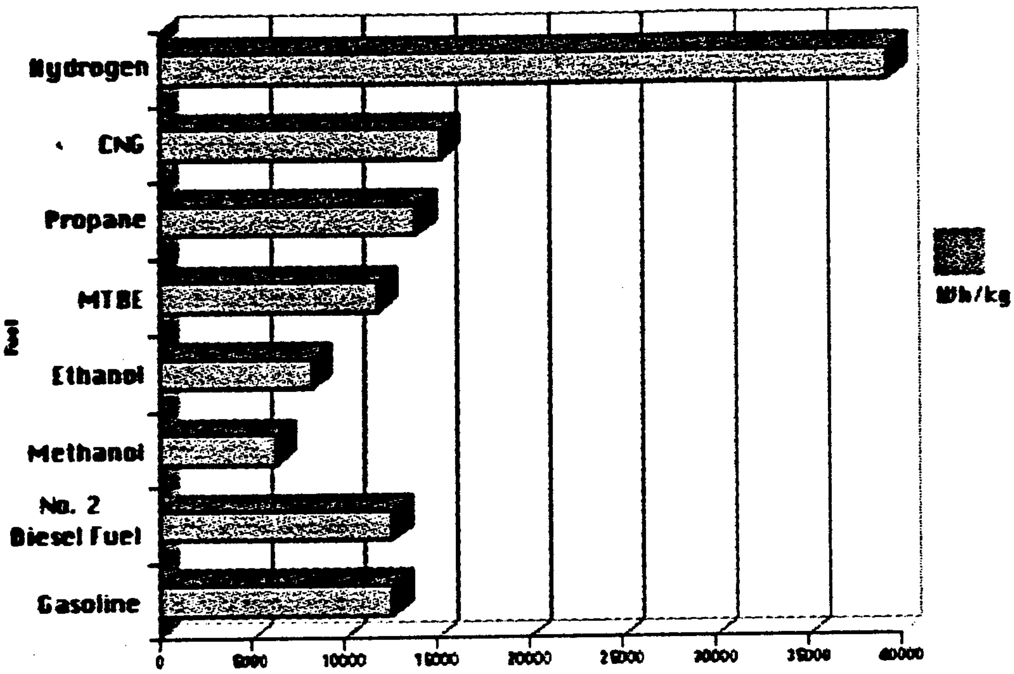


Figure 4-8. Specific Energy Density of Various Fuels

Since no prime mover is ideal, a careful consideration of the respective advantages and disadvantages is in process.

4.3.4.2 Motors

Several types of propulsion motors are being considered. The motors have to be rugged and reliable, hermetically packaged, have a high power density (> 1hp/lb), high efficiency to minimize cooling requirements, and sized for both the peak and continuous power required. The motor must also be high speed to allow the use of a fixed gear ratio transmission. Rotor construction limits must be compatible with motor maximum speed requirements.

All the candidate technologies are brushless due to the higher efficiency and thermal characteristics. However, brushless motors require that commutation of the fields be done electronically which increases the complexity of the electronics. Advances in the motor control technology have made this tradeoff worthwhile. A synopsis follows:

- Induction; Simple rugged design, low cost, high speed, but complex control electronics.
- Switched Reluctance; High performance. high speed, but high cost, complex control.
- Synchronous Reluctance; Emerging technology, uses simpler control electronics.
- Permanent Magnet DC; Easiest brushless to control, low speed efficiency, but exotic magnets are expensive, speed limited.
- Brush DC; Easiest to control, low cost, but low efficiency, brush wear, thermal issues.

Of the above motors reviewed, three are considered suitable:

- AC Induction; Currently favored technology due to motor simplicity and durability (no magnets). Speed control is more complex due to the fact that these motors are normally designed to run at a fixed speed where torque is proportional to rotor to rotating field slip. Sophisticated control techniques have been developed in the last five years which allow smooth rate control. The induction motor is a high speed motor.
- Permanent Magnet DC; Rotor consists of permanent magnets and is synchronized to the field rotation (motor currents are DC at stall). Simplest to control. High efficiency at low speeds. Motor speed limited by adhesion of magnets to rotor shaft. Newer technology rotor designs have increased top speeds.
- Synchronous Reluctance; New technology motors which combine the simple and rugged rotor design of a switched reluctance motor (a single piece) with the simple control of a Permanent Magnet motor with out the magnets. Very high speed. This is a prime candidate.

4.3.4.3 Drive Train

Several technologies are being evaluated for meeting gear reduction requirements. These approaches will minimize volume and have high power density. Consideration has also been given to motor in the wheel technology, however unsprung weight must be minimized for maximum mobility.

4.3.4.4 Energy Storage

Table 4-3 shows the relationships between specific energy, specific power and cost for a variety of energy storage mediums. The specific energy and specific power requirements of this vehicle could require a mix of technologies.

Table 4-3. Energy Storage Comparison

• **Requirement: 20 kWh, PWR** Selection Criteria Near Term *(Far Term)*

	Specific Energy	Specific Power	Cost
• Batteries	*Wh/kg*	*W/kg*	*$/kWh*
– Lead Acid	35 (48)	750	150
– NiMH	60 (95)	300	400
– Lithium	120 (500)	500 - 2K	10K (250)
– Zinc/Air	80	100	75
– Sodium/Sulfur	100	500	400 - 500
• Ultracapacitors			
– Organic (~100 V)	4	2000 (peak)	5K - 10K
– Aqueous (~400 V)	5	2000 (peak)	4K - 8K
• Flywheels (gimbaled) (or 2 counter rotating)	70	200	>10K
• Superconductors	TBD	TBD	TBD

24

4.3.4.5 Power Electronics

Four power electronic areas are being studied:

- Power devices
- Processors and low level electronics
- Power management software
- Control software

Power device technology has been making steady progress. The latest advances in IGBT (Insulated Gate Bipolar Transistor) technology makes them the standard device selection for the high voltage end. MOSFETs are still heavily used in the low voltage sections due to efficiency advantages. The most exciting advances are in the Silicon Carbide (SiC) devices, which allow for extremely high voltage and temperatures and therefore, smaller power devices.

Processors and low level electronics today are sufficiently mature to support the planned distributed control architecture. Motors that require electronic commutation algorithms need high speed processing at high motor rates.

Power Management Software is immature in the hybrid electric vehicle arena and will require development focus. Currently power management software is written for each specific hybrid configuration.

Control software will also need customization for the particular topology selected, but the current selection of high speed processors (and related chip sets) will support planned algorithms and architectures.

4.3.5 Modeling and Simulation

Some preliminary modeling was developed with the Hybrid Electric Combat Vehicle (HECV) Tool Box developed by the University of Texas. The intent for this software package is to evaluate the HEV concepts with regard to performance and energy management. The HECV Simulink software is very powerful, incorporating very detailed component models and provides an excellent, graphical user interface. Albeit powerful, the tool has two basic disadvantages. First, small changes can have a large ripple effect and secondly, the controller for each configuration needs to be specifically developed. Figure 4-9 is a sample model of a hybrid system and shows the individual blocks which can be mixed and matched to simulate the desired system.

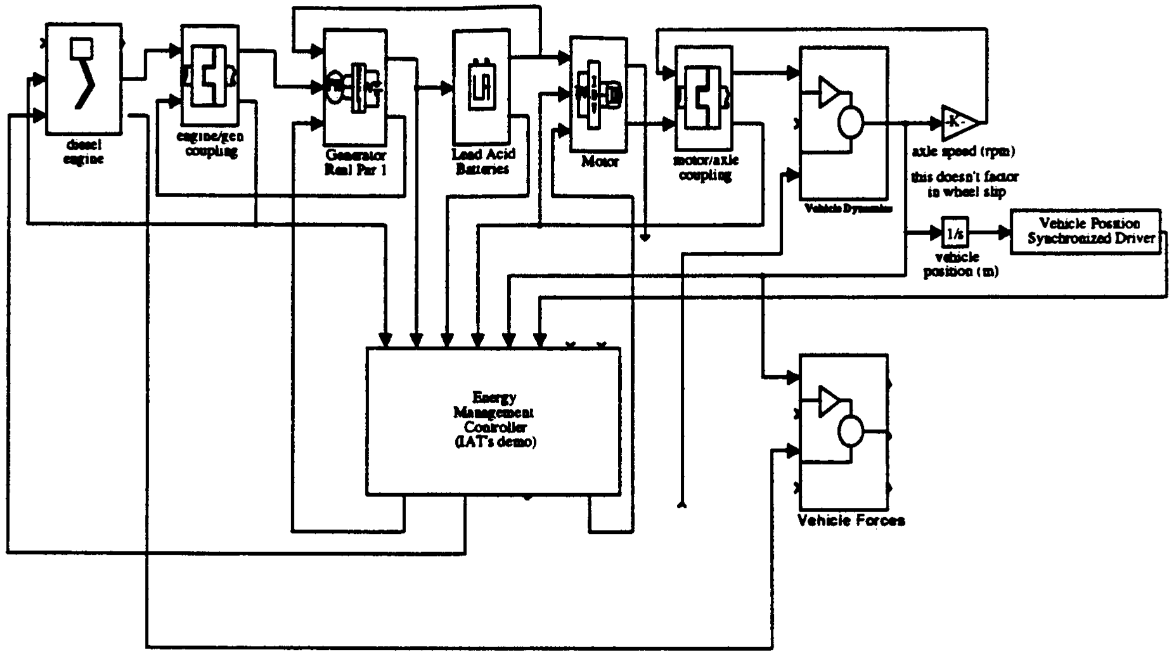


Figure 4-9. Sample HECV Tool Box Hybrid System Model

4.4 Survivability, Firepower, C4I

Our approach to date has been a bottoms-up approach based on mobility being the subsystem most critical to a superior vehicle concept. Concept development has focused on ensuring that key mobility requirements are met and that basic crew and firepower needs are met. Once the preferred hybrid electric drive concept has been detailed and incorporated with our RST Vehicle solid model and after incorporating built-in (mission dependent) armor as well as basic crew and firepower elements, future/emerging advanced survivability, weapons and C4I technologies will be incorporated within the remaining space claim areas of the RST Vehicle model.

In parallel with concepting and modeling preferred hybrid electric drive alternates, an independent research and development (IR&D) technology survey is being performed to identify the space, weight, power, and performance characteristics of candidate reconnaissance and light strike vehicle technologies primarily in the areas of survivability, firepower, and C4I. Initial focus will be on acquisition avoidance, threat detection, and target acquisition (reference Appendix G). Appendix H contains preliminary survey results in the survivability areas of acquisition avoidance and threat detection. Appendix I contains preliminary results in the area of firepower.

In reviewing and selecting appropriate technologies from this survey's results, our primary philosophy will be to:

- Focus on implicit stealth design features rather than bulky/heavy add-ons.
- Emphasize passive vs. active techniques due to limited space constraints.
- Pursue C4I technologies that facilitate "seeing before being seen/hit" without significant impacts on space/power claims.

In the armor area, the following considerations have been established:

- Weight, cost, and space claim make it impossible to armor up against all threats:
  - Heavy HMMWV cannot stop 7.62 AP.
  - Full protection against 7.62 ball, mortar fragments, and anti-personnel mines weighs 1700 lbs and costs about $100,000.
  - Armor detracts significantly from payload and mobility.
- Differing amounts of armor are best for differing missions:
  - Direct actions and shows of force require greater armor protection.
  - Reconnaissance, surveillance, etc. require mine protection combined with avoidance techniques and mobility.
- A mix of integral and configurable armor appears best:
  - Integral armor for wheel wells, floor panels, lower side panels, etc. Where mine protection is needed and attachment is difficult.
  - Add-on panels and windows as required.
  - Transporting, maintaining, and storing configurable armor panels is a logistics burden.
- End user perspective must be incorporated into design trade-offs to ensure appropriate selections are made. It is planned to obtain this perspective by interviewing ground weapons personnel at Quantico. Topics to be discussed are contained in Appendix C.

Additional armor information is contained in paragraph 6.

5. System Trade Studies

The initial topology trade studies which drove the remaining vehicle design concepts were whether the vehicle would be wheeled, tracked or half track. The speed and mobility requirements were assessed and evaluated in order to determine the preferred configuration. Intuitively, tracked and multi-axle wheeled configurations are heavier than a 4x4 AWD configuration and therefore do not score as well in terms of top vehicle speed, dash speed or acceleration. Tracked vehicles also have turning limitations which require that their length to width aspect ratio be between 1.7 and 1.9 which could be a limitation in cargo carrying capacity given the fact that the width is restrained to about 62" to fit the V-22. Conversely, tracked vehicles have better mobility in terms of lower VCI as shown in Appendix J (Extracted from Technical Report GL-88-16; Mobility Analysis for the TRADOC Wheeled Versus Tracked Vehicle Study - September 1988). A summary of similar findings is provided in Table 5-1.

From this study, it was evident that a 4x4 configuration was best in most areas. Mobility in terms of terrain passability and VCI was the only area where the 4x4 configuration was surpassed by all other candidate topologies. It was therefore concluded that a 4x4 configuration would be the best choice if the vehicle could meet the required VCI of 22.

Table 5-1. Tracked vs. Wheeled Qualitative Comparison

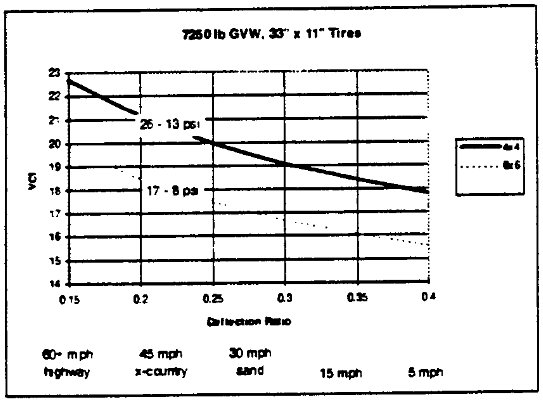
Criteria	Topology				
	Full-Track	**Half-Track**	**4x4 Wheeled**	**6x6 Wheeled**	**8x8 Wheeled**
Acoustic Noise	Poor	Poor	**Best**	Better	Better
Cost & Complexity	Poor	Good	**Best**	Better	Poor
Space Claim	**Best**	Good	Better	Poor	Poor
Mobility (Speed)	Poor	Poor	**Best**	Better	Good
Mobility (VCI & Terrain)	**Best**	Better	Poor	Good	Good
Ride Quality	Poor	Good	**Best**	Better	Better
Vulnerability*	Poor	Good	Good	Better	**Best**
Reliability	Poor	Good	**Best**	Better	Better

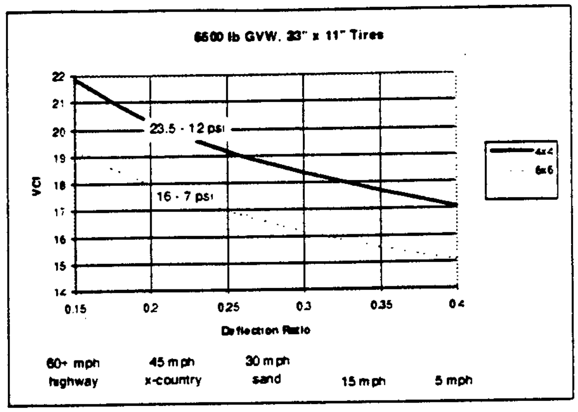
* Assumes the use of run-flat inserts in the wheeled configurations

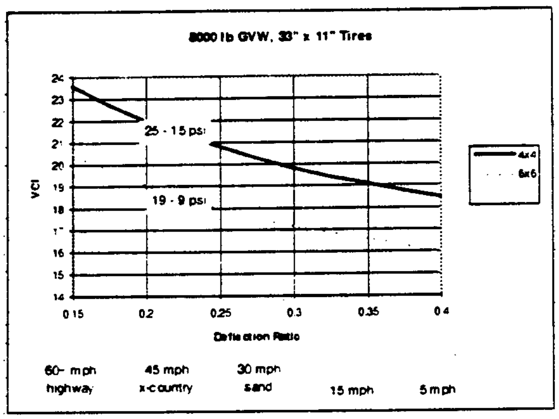
In order to determine if the 4x4 configuration would meet the VCI requirement, a study was performed using the mobility index calculations presented in report AMCP 706-356 and the VCI calculations reported in ADA 297810. Equations used as well as a sample calculation are shown in Appendix K. The following information should help put VCI into perspective. CI refers to soil cone index. The higher the soil cone index, the higher the soil strength. VCI is the minimum value of CI at which a vehicle can successfully complete N passes in the same ruts on level ground at a slow, steady speed. Generally, the lower the VCI, the better the vehicle's mobility.

- VCI is proportional to both ground pressure and tire pressure. As a rule-of-thumb, it is roughly equal to these values (within 25% or so). This is why wheeled vehicles with tire pressures in the range of 20-30 psi have VCIs around 20-30 and why tracked vehicles with ground pressures under 10 psi have VCIs under 10.
- CI less than six leaves a footprint greater than two inches deep due to ordinary walking.
- CI between six and 15 leaves a two inch deep footprint.
- CI between 15 and 23 leaves a one inch deep footprint.
- CI between 25 and 50 leaves a well defined footprint.
- Soil with a CI of about 100 can be easily penetrated with your thumb.
- Soil with a CI of about 150 can be penetrated with moderate thumb pressure.
- Soil with a CI of about 200 is very difficult to penetrate with your thumb.

Overall study results, summarized in Figure 5-1 and Table 5-2, show that a 4x4 vehicle with 33" diameter tires and an 11" tire patch width could meet the VCI requirement of 22 at highway pressures and a GVW of 6,500 pounds or less. However, in order to obtain the desired objective VCI of 15, a 6x6 configuration with CTIS would be required. Based on this fact, it was decided to retain a 6x6 configuration as a backup approach to the 4x4 baseline. The VCI calculations are believed to be conservative since our calculations showed the Surrogate Fast Attack Vehicle to have a VCI of 23.6 versus an empirical value of 22 as reported in "Results of Mobility Tests on the Surrogate Fast Attack Vehicle" (Technical Report GL-84-9, Table 1, R. Gillespie, September 1984).







- Calculations are conservative
- Latest Propulsion System Technology May Improve VCI
- 4x4 can meet VCI at 7250 lb GVW with 11.5" wide tires
- 4x4 can meet VCI at 8000 lb GVW with 12" wide tires

Figure 5-1. VCI vs. Tire Deflection Ratio

Table 5-2. Tracked vs. Wheeled VCI Comparison

4x4 vs 6x6 TRADES							
Drive	Tire Dia x Width (16.5" Wheel Dia)	GVW (lb)	VCI at Highway Pressures (15% deflection)	Highway Pressure (psi)	VCI with CTI at low pressure	CTI Low Pressure (psi)	Comments
4x4	31" x 11"	8000	23.6	32	18.5	20.1	Difficulty meeting step climb & ground clearance
4x4	33" x 11"	8000	23.6	29	18.5	18.4	Tire diameter is not in the VCI equation and only affects pressure
4x4	33" x 12"	8000	22.0	26.5	17.3	16.8	Meets VCI Spec
4x4	33" x 11.5"	7250	22.0	26.2	17.2	16.6	Meets VCI Spec
4x4	33" x 11"	6500	21.9	23.5	17.1	15.0	Meets VCI Spec
6x6	31" x 11"	8000	20.5	21.2	16.0	13.4	Meets VCI Spec
6x6	33" x 10"	8000	21.8	21.2	17.0	13.5	Meets VCI Spec
6x6	33" x 12.5"	8000	19.1	17.0	15.0	10.8	Meets VCI spec and VCI goal at low pressures (possibly achieved with CTI). Tire width is difficult to package
6x6	33" x 9.5"	7250	21.8	20.3	17.0	12.8	Meets VCI Spec
6x6	33" x 9.0"	6500	21.8	19.2	17.0	12.2	Meets VCI Spec
6x6	33" x 11"	6500	19.3	15.7	15.1	10.0	Can meet the goal with CTI.

Notes:
1. VCI Spec is 22 with a goal of 15.
2. 4x4 configurations can meet the 22 spec limit for a GVW range of 6500 - 8000 lb at reasonable tire widths. VCI can be improved with CTI but will still not reach the desired goal of 15 (meets 17).
3. 6x6 configurations can meet the 22 spec limit for a GVW range of 6500 - 8000 lb at reasonable tire widths and can meet the goal of 15 if supplemented by CTI.

It is planned to confirm the 4x4 selection by applying NRMM as well as to reassess the selection for a hybrid electric drive configuration after hybrid electric drive components are further defined. The first NRMM analysis performed by LMDS has been to consider a modification to an existing and well characterized vehicle (narrowing a HMMWV to fit the V-22 width restrictions). This was accomplished by using an input file for the M1025 Armament Carrier HMMWV (A WES Standard) and running it over a Lauterbach terrain map and comparing these results to an identical simulation, but with the HMMWV's width reduced by two feet to fit the V-22. The results are shown in Appendix L. Note that both vehicles performed similarly in terms of speed under every condition except maneuvering around vegetation & obstacles, sliding on curves and tipping on curves. The narrower vehicle was able to achieve higher speeds around vegetation and obstacles because of its smaller size. However, it performed worse on curves limiting the speed to less than 5 mph and also being limited due to tipping which was never a problem with the baseline HMMWV configuration. These results were expected and are the main reason for either a retractable suspension concept or active suspension to counteract the effects of the narrow track width resulting from the V-22 transportability requirement.

The second bar chart in Appendix L is for the same comparison except it shows terrain "NoGo". As expected, the narrow vehicle has more "NoGo" than the baseline configuration (0.5% vs zero) due to tipping on side slope but also performs better in obstacle clearance interference due to its smaller size.

A concept layout of the RST vehicle is shown in Figure 5-2. It accommodates a three person crew consisting of a driver, commander (front passenger) and an operator in the back situated between the rear wheels. There is plenty of room on either side of the operator (above the wheel wells) for sensors and other necessary reconnaissance equipment and combat gear.

A remote controlled stabilized gun mount can be fitted to the roof, as shown in Figure 5-3 (once the vehicle has been driven out of the V-22) for use with either the MK19 grenade launcher or the M2 HB 50 caliber machine gun as a primary weapon. M240G machine guns could also be mounted to both door posts on 240° articulated swing-arm mounts. Figure 5-3 is also a cross-section of the vehicle layout which shows the occupant leg room and head room. Figure 5-4 is a perpendicular cross-section which shows the shoulder room.

The exterior of the vehicle can be protected by a combination of integral armor which provides floor and wheel well protection from anti-personnel mines & smaller anti-tank mines and door panel armor for personnel protection from small arms fire. Appliqué armor can also be supplied to supplement the integral armor to provide protection from 7.62 mm NATO ball or 7.62 mm AP at 0° obliquity. In addition to armor, the vehicle exterior can be treated with anti-reflective coatings and chameleon-like paints to reduce its visual signature. A skirt could also be added to minimize the visual signature associated with road and trail dust and low road noise tires can be used to minimize the acoustical signature.

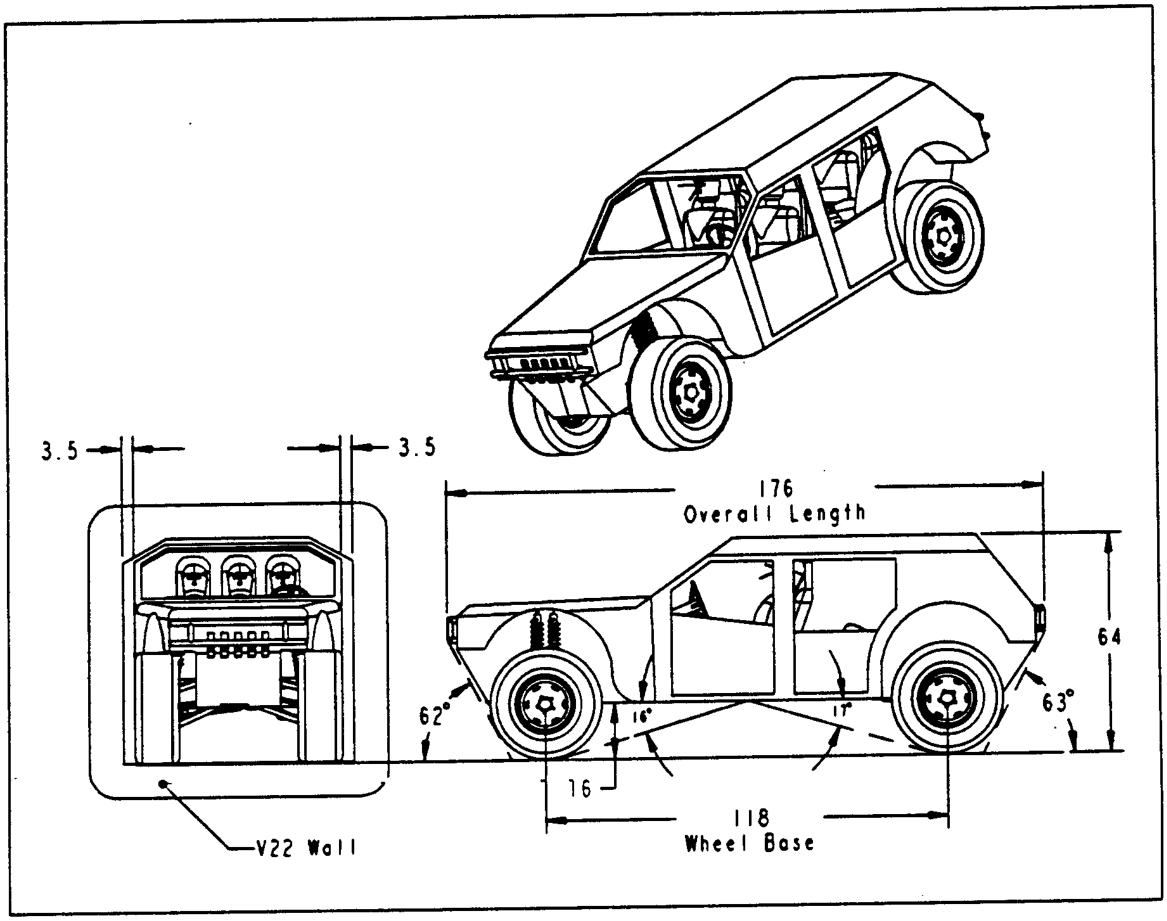


Figure 5-2. RST Vehicle Concept Layout

For maximum grade climbing, the ICE is located in front to shift the CG as far forward as possible. The ICE fits between the front A-arm suspensions as shown in Appendix M. The rear suspension uses progressive independent trailing arms. Due to the narrow vehicle width, and the desired amount of wheel travel, the turning circle can become a difficult requirement to meet. Our experience with conventional steering geometries indicates that a 28° wheel angle is about the maximum that can be accommodated with off the shelf CV joints and axle half shafts. A wheel base of 118" (comparable to the JTEV concept), and a track width of 61", can meet a turning circle radius of 24 feet and keep within the 28° recommended limit. The effects of wheel base and track width on front engine mounting clearance are shown in Figure 5-5 for a 25 foot turning circle.

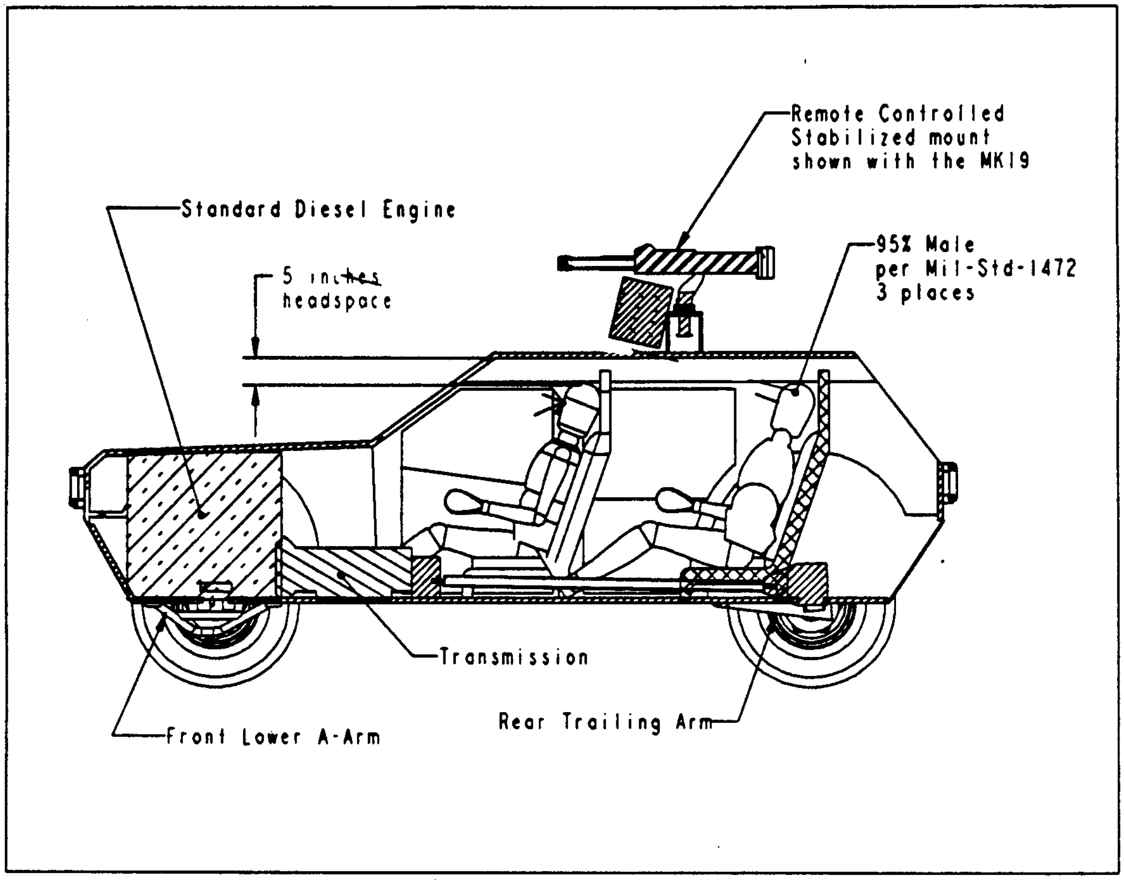


Figure 5-3. RST Vehicle Cross Section

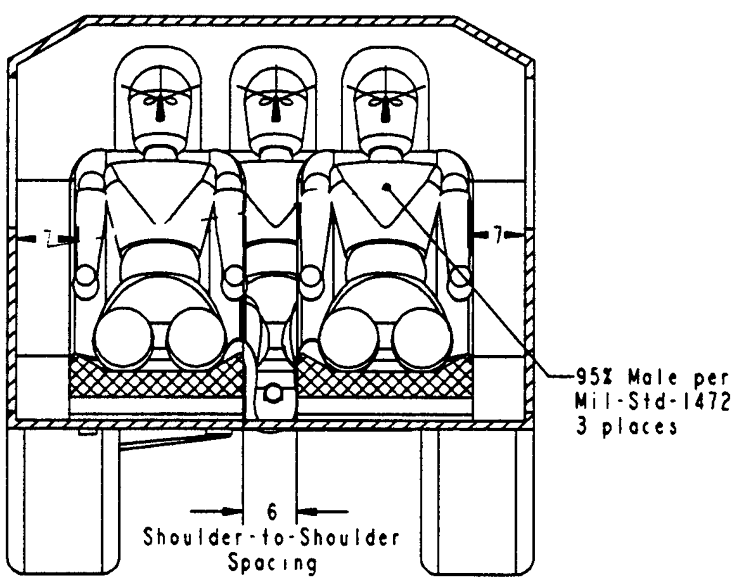


Figure 5-4. RST Vehicle Perpendicular Cross Section

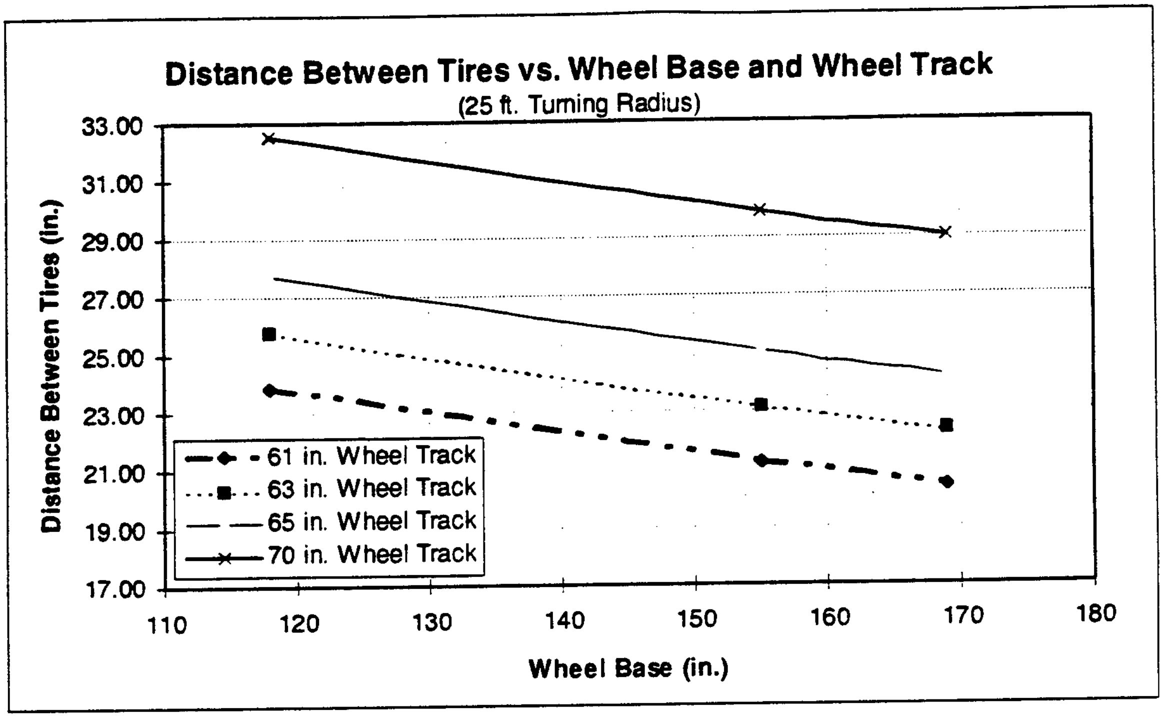


Figure 5-5. Distance Between Tires vs. Wheel Base and Wheel Track

Other configurations which would also fit the V-22 internal cargo dimensions are as follows:

Wheel Base (in)	Ground Clearance (in)	Max Wheel Angle for 25 ft turn (degrees)
118" (JTEV)	16"	26
129"	10" stowed (16" ride)	28
155"	16"	32
169"	18"	35

Once the wheel base exceeds 155", the ground clearance must be increased in order to meet ramp over. However, this causes other problems with occupant head room. An optimum configuration appears to be between 118" and 155" wheel base. In order to fit a four person crew, the rear leg room requires a wheel base of at least 142". If the crew is limited to 3 persons, a wheel base of 118" is sufficient. LMDS has a proprietary retractable suspension geometry which allows for a 129" wheel base vehicle with a stowed ground clearance of 10". Once the vehicle exits the V-22 the track width is extended and the ground clearance increases to 16" (see Appendix N). This not only meets ramp over, turning circle, and ground clearance, but it also increases the track width to enhance side slope and cornering stability. Figure 5-6 depicts the concept vehicle on a 40% side slope with a 61" track width.

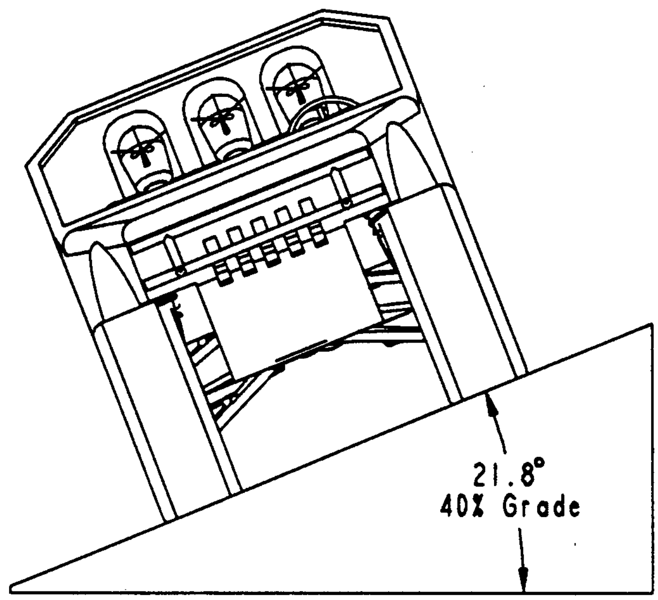


Figure 5-6. RST Vehicle Side Slope Perspective

Statically this concept can survive a 100% grade if its CG is less than 25" off the ground as shown in Figure 5-7. This situation is improved to about 112% if the track width is increased by a retractable mechanism to about 62 inches (measured from tire patch center to tire patch center).

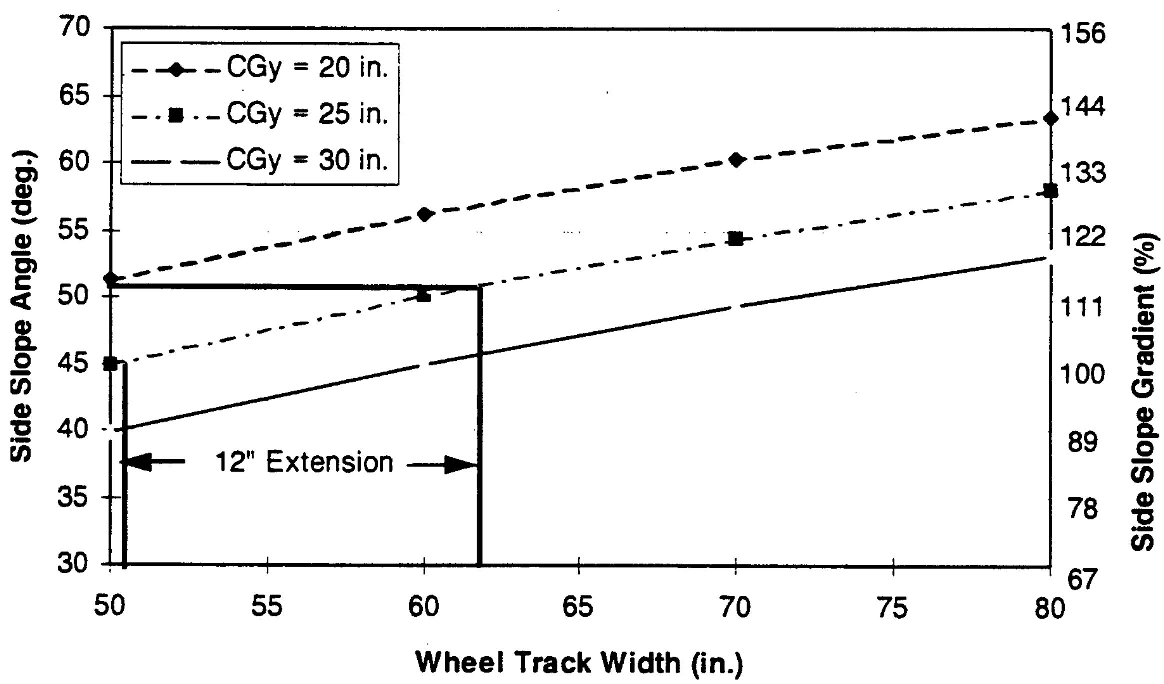


Figure 5-7. Point of Incipient Roll

Track width will also help cornering stability as shown in Figure 5-8. This figure illustrates the effects of CG height on holding a 0.6g lateral acceleration as a function of track width. Note that a vehicle with a 61" track width would require its CG to be less than 25.5" while a 74" wide vehicle would perform similarly with the CG as high as 30.5".

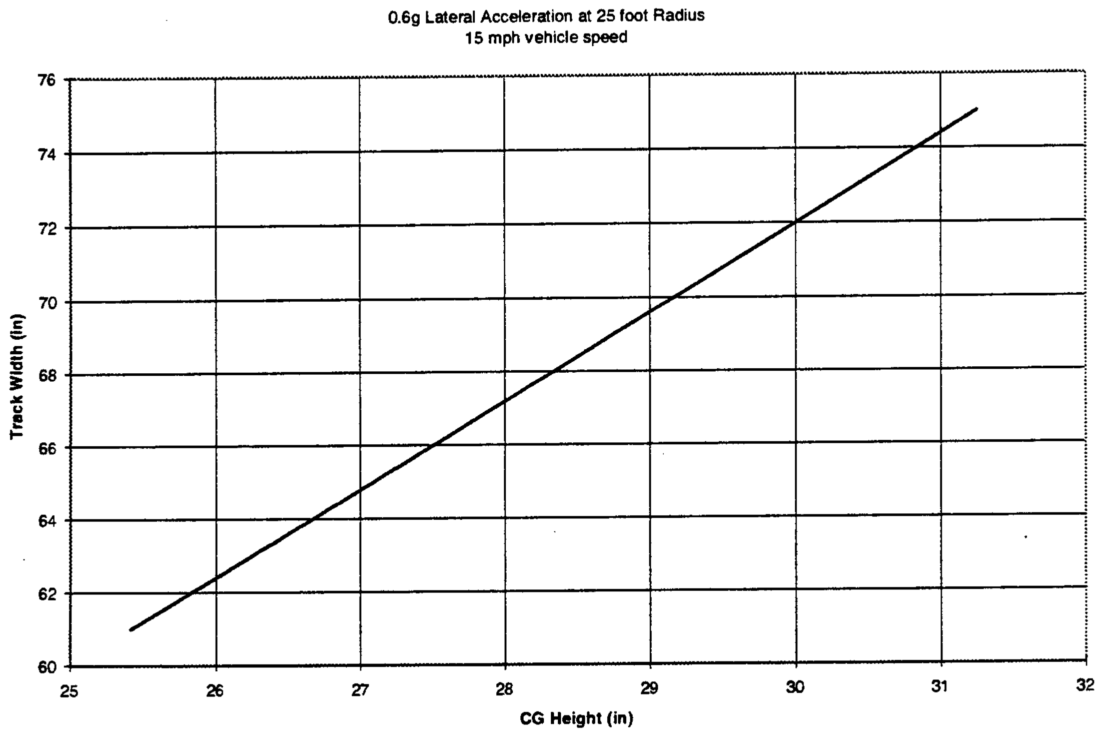


Figure 5-8. Track Width vs. Cornering Stability

A color picture of the concept vehicle with a conventional propulsion system is shown in Figure 5-9 with a translucent chassis so that some of the internal details can be seen. Appendix O contains additional vehicle perspectives including seating capacity, weapons mounted, and a litter variant.

Figures 5-10, 5-11, and 5-12 show initial concept vehicle perspectives that incorporate hybrid electric drive components. These perspectives are preliminary and will be updated based upon on-going hybrid electric drive component tradeoffs.

The hybrid electric drive system differs from the conventional propulsion system approach in that the driver is located between the front tires with the crew seated side-by-side and behind. This potentially improves driver vision and increases the storage space in the back of the vehicle for cargo storage.

The ICE is a combination turbine alternator. It weighs only 175 pounds and measures about 12" x 20" x 30". The batteries are polymer-lithium sheets and are placed along the floor and wheel wells to both lower the vehicle's CG and to augment the vehicles integral armor protection. The locations and thickness of the battery sheets are shown in Figures 5-11 and 5-12. The motors are each about 45 pounds, 0.5 ft^3 volume and shown mounted on top of the spring/damper assemblies. A trade-off is underway to determine if the best motor location is as shown or at the hub assemblies. The hybrid electric vehicle configuration shown has the advantage of having

components being somewhat protected from the road debris by being mounted in the crew areas and might lower the unsprung weight since the motors are attached to the vehicle chassis. In this configuration, the rotary motion from the motors is transmitted through a vertically oriented shaft into a right angle gearbox with a bevel gear set at each wheel to change the rotation from the vertical orientation to horizontally located axles. The motor shaft will have to have telescoping capabilities (about 16") to accommodate the range of wheel travel needed to traverse rough terrain.

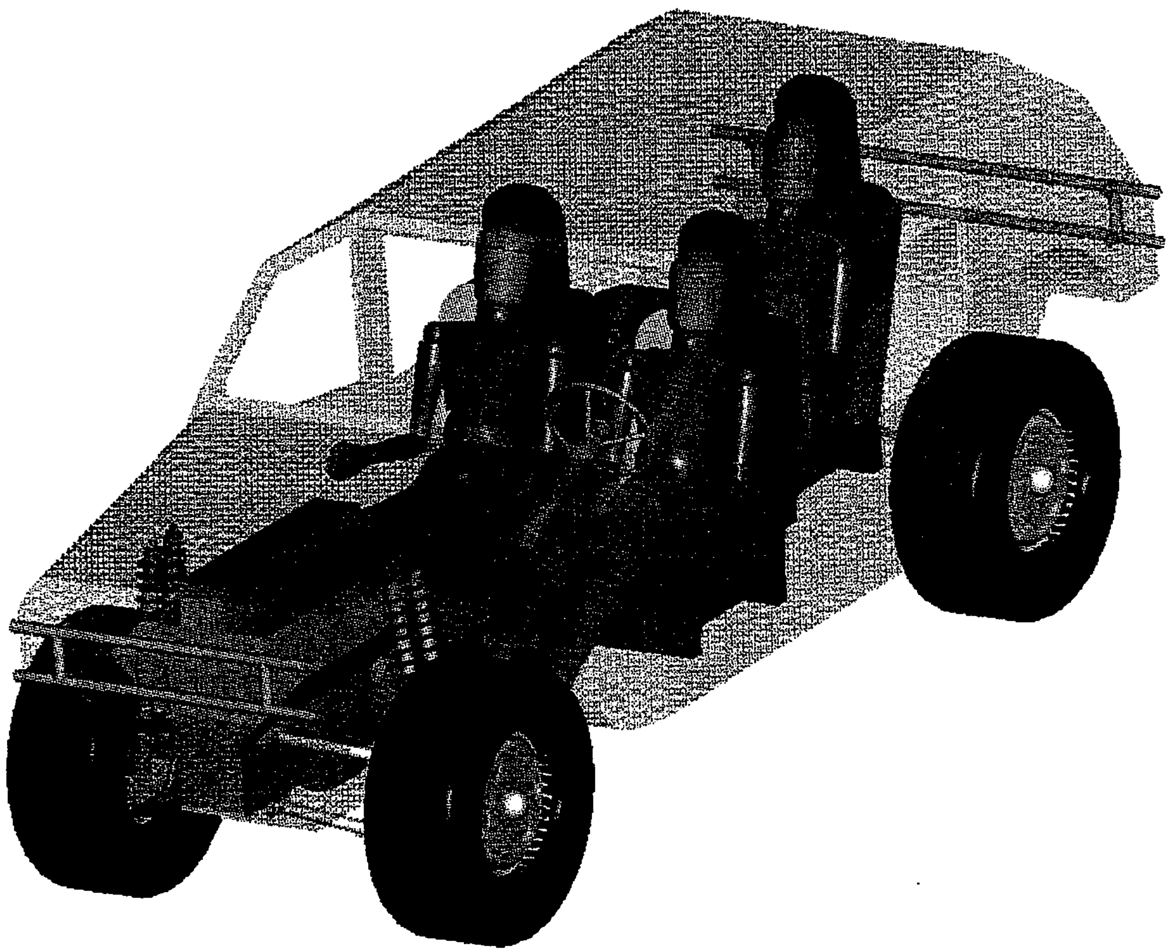


Figure 5-9. RST Concept Vehicle with Standard Propulsion System

The shock tower assemblies include a coil spring, also mounted to the chassis, and located concentrically around the motors to isolate the sprung mass and keep the tires in contact with the terrain as much as possible. Dampers, or shock absorbers, are not shown but could either be located concentric to the motor shaft or multiple absorbers could be nested circumferentially around the motors shaft. Steering is envisioned to be accomplished by rotating the bevel gearbox/axle assembly about the vertical centerline of the shock tower assembly.

around the motors shaft. Steering is envisioned to be accomplished by rotating the bevel gearbox/axle assembly about the vertical centerline of the shock tower assembly.

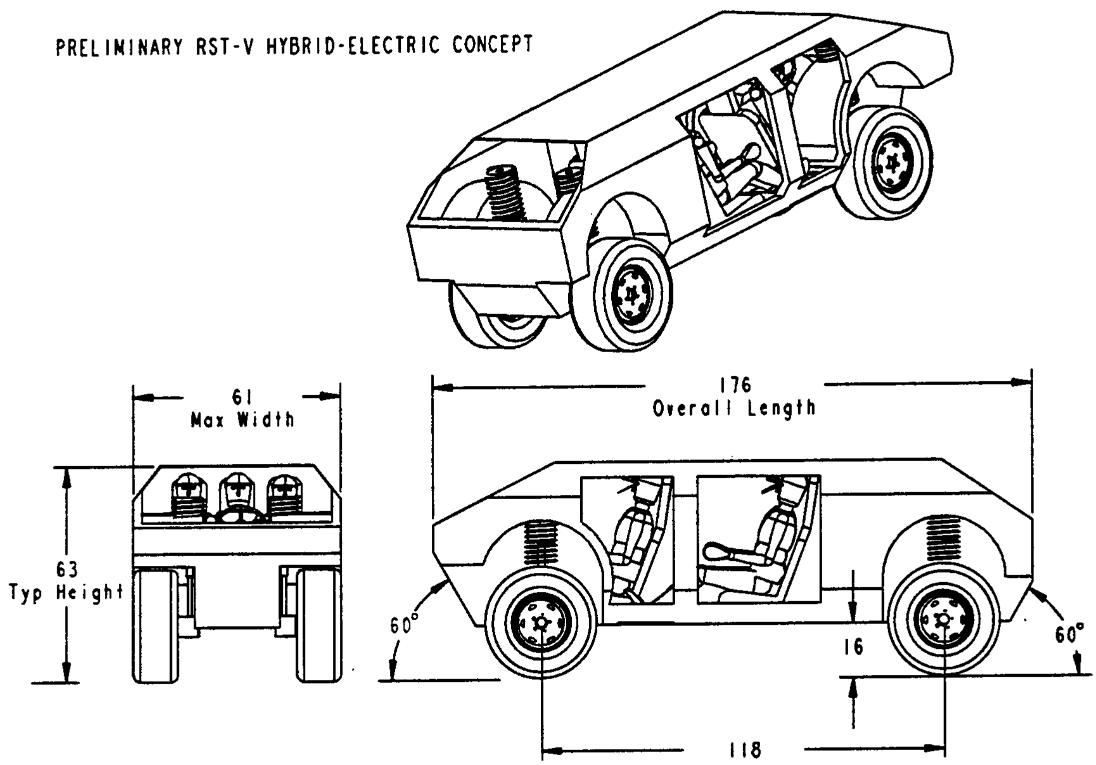


Figure 5-10. RST Hybrid Electric Drive Vehicle Concept Layout

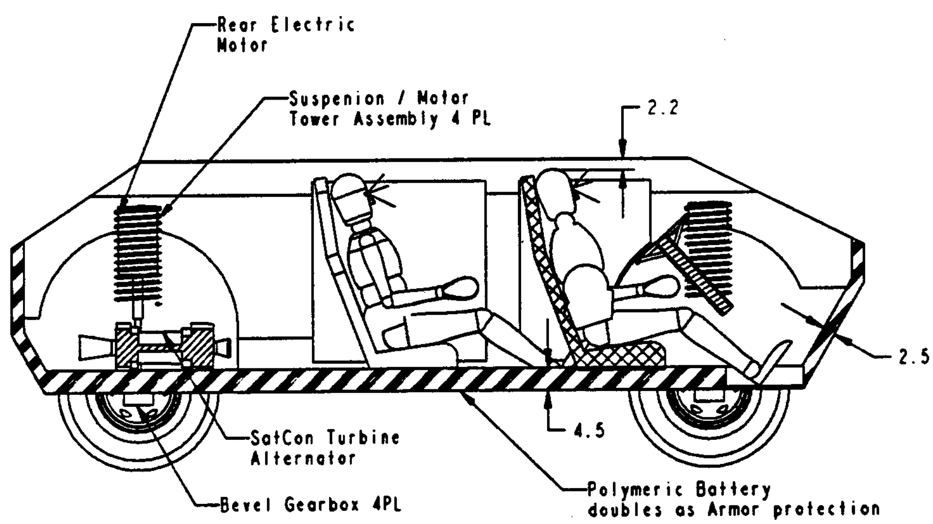


Figure 5-11. Hybrid Electric Drive System - Longitudinal Cross Section

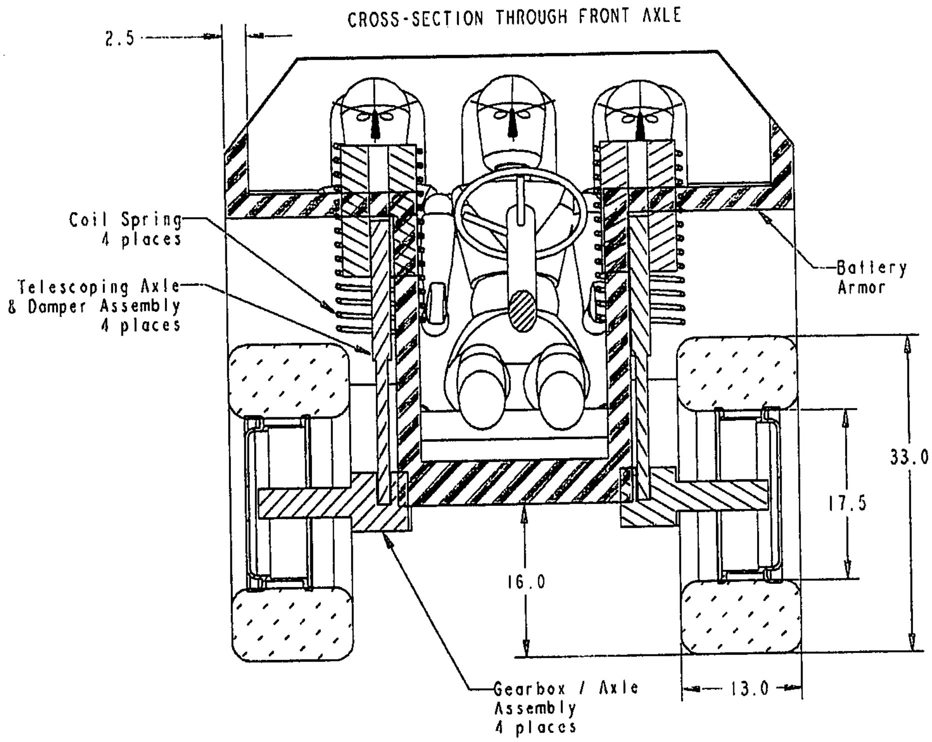


Figure 5-12. Hybrid Electric Drive System - Perpendicular Cross Section

A color picture of the concept vehicle with a conventional propulsion system is shown in Figure 5-13 with a translucent chassis so that some of the internal details can be seen.

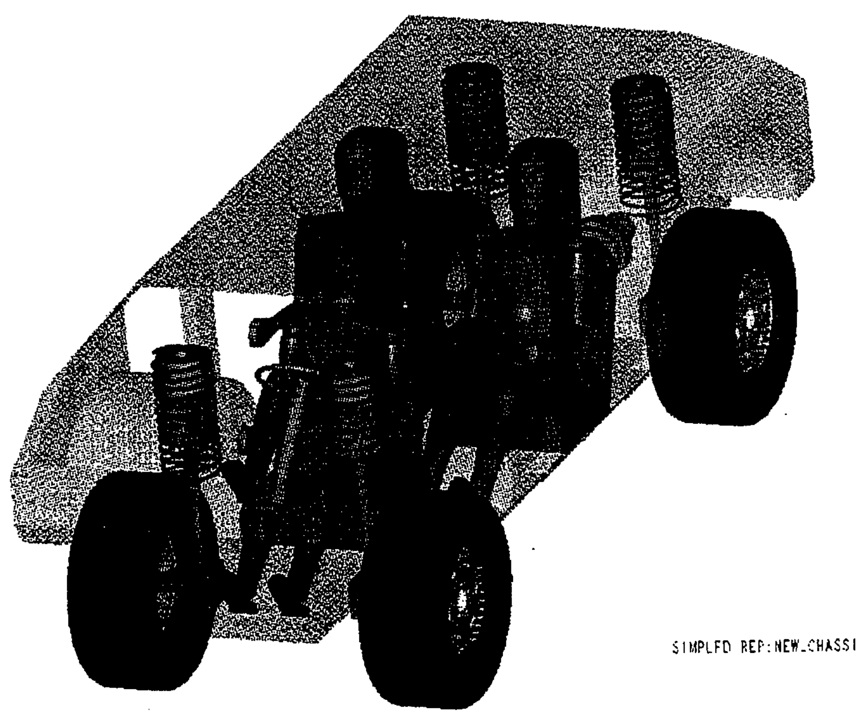


Figure 5-13. RST Concept Vehicle with Hybrid Electric Drive System

6. Vehicle Weight Analysis

6.1 Overview

The overall objective of this initial Vehicle Weight Analysis was to compile a detailed list of vehicle component weights and develop a weight allocation profile for the four different vehicle mission variants and three different weight levels. From this profile, the optimum use of the weight allocations and the positioning of the weight can be determined.

6.2 Approach

The initial step in the weight analysis was the definition of the terminology for the general weight categories and the specific vehicle components. Then, a spreadsheet was set up in Microsoft Excel to perform the evaluation. The four different mission variants were evaluated separately. Information on individual component weights was gathered and entered into the spreadsheet. A weight analysis was performed with the weight threshold of 6500 pounds as an objective. This threshold was chosen based on engineering judgment of the minimum achievable weight with the desired mobility characteristics. Additional analyses are to be conducted for thresholds of 8000 pounds, the RST-V weight limit, and an intermediate weight of 7250 pounds.

Figure 6-1 displays the general categories and some of the specific components in each category. The *Gross Vehicle Weight* was separated into two general categories: (1) the *Curb Weight*, i.e., the basic vehicle weight independent of the mission; and (2) the *Payload Weight* specific to each mission. The *Curb Weight* was further broken down into three subcategories: *Empty Vehicle*, *On-Vehicle Basic Equipment*, and *On-Vehicle Basic Consumables*. The *Empty Vehicle* weight is composed of the bare essentials for a rolling, powered chassis including the frame, body, engine, drivetrain, and the essential auxiliary components like the battery. Also included is built-in armor which is envisioned to be an integral part of the chassis and represents the minimum armor suite common to all mission variants. The *On-Vehicle Basic Equipment* consists of essential Communications/Navigation equipment, Controls & Displays, and Accessories such as a fire extinguisher. *On-Vehicle Basic Consumables* includes essential fluids such as a full tank of fuel, engine oil, and coolant fluid in the engine, but does not include spare fluids.

The *Payload Weight* was broken down into five subcategories: *Vehicle-Mounted Weapons & Ammunition*, *Personnel & Personal Equipment*, *Consumables*, *Configurable Armor*, and *Other Mission Equipment*. *Vehicle-Mounted Weapons & Ammunition* encompasses several weapons options depending on the mission. *Personnel & Personal Equipment* covers the crew and passengers and their personal equipment such as helmets and armored vests. *Consumables* includes food rations, cooking stoves, and the water supply. *Configurable Armor* is armor in addition to the built-in armor that can be added to the vehicle in a mission-dependent configuration. Finally, *Other Mission Equipment* encompasses Communications/Navigation and Surveillance & Observation equipment that are very much mission-specific, and additional logistics equipment and/or litters for the "Log & Litters" mission variant.

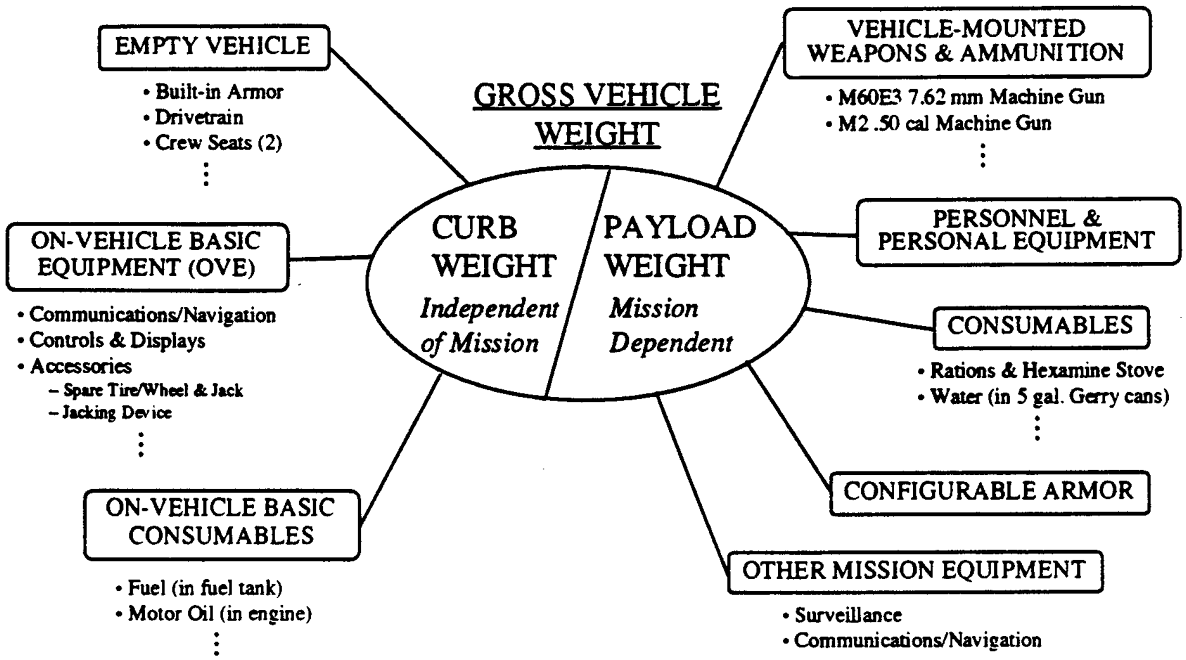


Figure 6-1. Suggested Vehicle Weight Categories

6.3 Analysis and Discussion

A summary of the Vehicle Weight Analysis for a minimum weight vehicle is given in Table 6-1. Details of the analysis are provided in Appendix P. This paragraph gives details of the analysis performed to date along with further discussion of several categories that require clarification. The weight estimates included will be further evaluated during the design and integration phase of the contract to develop appropriate baseline weight estimates for each mission variant and each weight threshold.

The *Curb Weight* is exactly the same for all four missions since the *Curb Weight* is independent of the mission. The engine and drivetrain weights are based on a standard diesel propulsion system. However, placeholders have been included in the spreadsheet for Hybrid Electric Drive components which are currently being evaluated. Built-in armor weighing 1047 pounds is also incorporated in the Empty Vehicle Weight since this armor may be an integral part of the chassis. This built-in armor includes underbody armor which meets NIJ level IV requirements, along with lighter weight armor around the passenger compartment which meets NIJ level IIIA requirements. Table 6-2 describes the armor selections for each mission variant.

Since the elements of *Payload Weight* were selected for each mission, the estimated weights for the missions vary from one another. The armor selections for each mission are a function of the perceived likelihood of need for armor in each mission. The RST mission required some Vehicle Mounted Weapons and Ammunition, and some additional consumables because of the time duration of the mission, but was not allocated additional armoring, because the theme of the mission is to avoid being detected. The resulting *Gross Vehicle Weight* was less than our objective weight. In contrast, the Strike mission, which requires even more Vehicle Mounted Weapons and Ammunition, is assessed to also require substantial additional armor because of the likelihood of being shot at, thereby driving the *Gross Vehicle Weight* well beyond our objective.

Table 6-1. Vehicle Weight Summary Example

CATEGORY/ITEM	RST		Strike		Personnel		Log & Litters	
	Qty	Weight (Lbs)	Qty	Weight (Lbs)	Qty	Weight (Lbs)	Qty	Weight (Lbs)
EMPTY VEHICLE								
Hull		722.0		722.0		722.0		722.0
Suspension & Steering		737.0		737.0		737.0		737.0
Engine (Standard Propulsion System)		865.2		865.2		865.2		865.2
Drivetrain (Standard Propulsion System)		464.0		464.0		464.0		464.0
Hybrid Electric Drive System		N/A		N/A		N/A		N/A
Built-in Armor (Mine Attack)		1047.0		1047.0		1047.0		1047.0
Electrical Systems		178.0		178.0		178.0		178.0
ON-VEHICLE BASIC EQUIPMENT								
Communications/Navigation		105.9		105.9		105.9		105.9
Controls & Displays		18.0		18.0		18.0		18.0
Accessories		220.2		220.2		220.2		220.2
ON-VEHICLE BASIC CONSUMABLES (Fuel, Oil, etc.)		197.0		197.0		197.0		197.0
CURB WEIGHT		**4554.3**		**4554.3**		**4554.3**		**4554.3**
VEHICLE-MOUNTED WEAPONS & AMMUNITION								
M60E3 7.62mm Machine Gun		94.8		118.8		94.8		86.8
M60E3 Ammunition (# of rounds)	800	70.0	2000	175.0	800	70.0	400	35.0
M2 .50 Cal Machine Gun		213.2		261.2				
M2 Ammunition (# of rounds)	400	116.0	1000	290.0				
PERSONNEL & PERSONAL EQUIPMENT								
Crew & Passengers	3	525	3	525	5	875	3	525
Personal Equipment	3	317.0	3	317.0	5	592.6	2	210.6
CONSUMABLES (Rations, Stove, Water, etc.)		160.5		85.5		92.5		121.5
CONFIGURABLE ARMOR (Small Arms/Frag Attack)		0		882.0		882.0		0
OTHER MISSION EQUIPMENT								
Communication/Navigation		127.8		127.8		29.8		76.8
Surveillance & Observation Equipment		53.9		44.0		39.6		39.6
Logistics Equipment & Litters		0.0		0.0		0.0		900.0
PAYLOAD WEIGHT		**1678.2**		**2826.3**		**2676.3**		**1995.3**
GROSS VEHICLE WEIGHT		**6232.5**		**7380.6**		**7230.6**		**6549.6**

The Personnel mission was assessed to require additional armoring, because we anticipate being required to transport personnel into dangerous areas. This weight, along with the addtional weight of the personnel being transported, also drives the *Gross Vehicle Weight* for this mission beyond our objective. For the Litters and Logistics mission, we chose not to add the additional armoring, because this mission is more likely to be executed behind friendly forces, althought some cases may exist where additional armoring is desireable for cargos which require additional protection. The *Gross Vehicle Weight* for this mission was very close to our objective weight.

Table 6-2. Vehicle Armor Calculations

INTEGRAL ARMOR (NIJ IV-underbody, NIJ IIIA-body):

	Area (ft^2)	Thickness (in)	Weight (lbs)	Applies to Variant*:
Front wheel wells (2)	22.9	1	125.95	R,S,P,L
Firewall	11.9	1	65.45	R,S,P,L
Engine pan	7.3	1	40.15	R,S,P,L
Floor pan (incl. tunnel)	40	1	220	R,S,P,L
Rocker panels (2)	5.8	1	31.9	R,S,P,L
Partial rear wheel wells (2)	18	1	99	R,S,P,L
Rear bulkhead	15.5	1	85.25	R,S,P,L
Partial front 1/4 panel (2)	6	0.25	7.5	R,S,P,L
A post (2)	3	0.25	3.75	R,S,P,L
Front door (2)	13	0.25	16.25	R,S,P,L
B post (2)	3.5	0.25	4.375	R,S,P,L
Rear door (2)	12.5	0.25	15.625	R,S,P,L
Rear 1/4 panel (2)	11.4	0.25	14.25	R,S,P,L
Rear hatch	9.2	0.25	11.5	R,S,P,L
Roof	39.6	0.25	49.5	R,S,P,L
Windshield	7.5	1.33	112.5	R,S,P,L
Front door glass	2.4	1.33	36	R,S,P,L
Rear door glass	2.4	1.33	36	R,S,P,L
Rear glass	4.8	1.33	72	R,S,P,L
		Sum =	1046.95	R,S,P,L

CONFIGURABLE ARMOR (NIJ IV when over integral armor):

Partial front 1/4 panel (2)	6	0.75	25.5	S,P
A post (2)	3	0.75	12.75	S,P
Front door (2)	13	0.75	55.25	S,P
B post (2)	3.5	0.75	14.875	S,P
Rear door (2)	12.5	0.75	53.125	S,P
Rear 1/4 panel (2)	11.4	0.75	48.45	S,P
Rear hatch	9.2	0.75	39.1	S,P
Roof	39.6	0.75	168.3	S,P
Windshield	7.5	1.7	120	S,P
Front door glass	2.4	1.7	38.4	S,P
Rear door glass	2.4	1.7	38.4	S,P
Rear glass	4.8	1.7	76.8	S,P
Front fascia	7.4	1	48.1	S,P
Hood	22	1	143	S,P
		Sum =	882.05	

* Weight R (RST) Variant =	1046.95	lbs.
Weight S (Strike) Variant =	1929	lbs.
Weight P (Personnel) Variant =	1929	lbs.
Weight L (Litters/Logistics) Variant =	1046.95	lbs.

Armor is Spectra and Spectra/Boron carbide composite and polycarbonate/glass

Wheelbase is 118"

APPENDIX A

RST-V System/Segment Specification Comments

RST-V System/Segment Specification Comments

Paragraph Number	Paragraph Title	Comment
1.	**SCOPE**	Scope could be expanded to indicate program objectives. It should be noted that this is a development spec, not an acquisition spec.
1.1	IDENTIFICATION	
1.2	SYSTEM OVERVIEW	
1.3	DOCUMENT OVERVIEW	
2.	**APPLICABLE DOCUMENTS**	
2.1	GOVERNMENT DOCUMENTS	With the requirements for Arctic operations MIL-L-46167 Lubricating oil, ICE, Arctic will be required also. (Maybe 21267 for break-in & storage?)
2.2	NON-GOVERNMENT DOCUMENTS	
2.2.1	Precedence of Documents	
3.	**SYSTEM REQUIREMENTS**	
3.1	DEFINITION	
3.1.1	**Mission Order of Precedence**	Suggest changing to "RST-V, Weapons/Light Strike, Personnel, and Litters/Logistics". Suggest describing how these priorities should be used in driving vehicle design and how they relate to precedence in section 3.8.
3.1.2	Baseline Platform	Reword to "...accommodate a variety of mission variants..."
3.2	CHARACTERISTICS	
3.2.1	**Performance Characteristics**	
3.2.1.1	**Weight**	Implies vehicle must weigh 8000 pounds. Rewrite to allow for vehicles with curb weight less than 5000 pounds.
3.2.1.1.1	Gross Vehicle Weight (GVW)	Clarify GVW is a maximum and that payload is a minimum. Don't constrain curb weight. In Table 1, *curb weight* and *margin of uncertainty* should be eliminated as parameters to be specified. *Maximum GVW* and *payload* are sufficient. Also, we recommend elimination of separate specifications for weights for separate missions, since the specification applies to a single vehicle (eg, RST-V). We suggest using one basic vehicle, with differences in payload, if different missions are to be accomodated. We suggest using more standard nomenclature, as we defined in IPR 2. These notes also apply to sections 3.2.1.1.2 and 3.2.1.1.3.
3.2.1.1.2	Curb Weight	It would be nice to have an estimate of the weight of the OVE listed. Suggest moving 3.2.3.1 and table 6 to this weight section (3.2.1.1). It is not necessary to itemize payload items in this paragraph.
3.2.1.1.3	Payload	Several items required by the spec are not listed as payload making up GVW. Doors and deep water fording kits need to be accounted in payload somewhere. The payload weight list is all ROM and needs further definition. Crewman weights are not the same as those used in the weight allocations at IPR 2, nor the same as those provided by Jeff Bradel. The conversions from pounds to kilograms should be correct if they're included.

Paragraph Number	Paragraph Title	Comment
3.2.1.1.4	Margin of Uncertainty	The weight uncertainty should be dealt with in the design process, not as a specified value. The GVW is a spec value which the design should meet.
3.2.1.2	**Mobility**	Suggest adding a conditional statement of meeting these requirements with a vehicle at normal operating temperature unless otherwise specified. It is not practical to expect forward motion of a vehicle within 10 sec. after master power with a cold diesel engine and/or torque converter transmission.
3.2.1.2.1	Speed	There are no references to reverse speed capabilities. Should provide a minimum reverse speed requirement.
3.2.1.2.1.1	Forward Speed	60 (75) MPH. Demands a very high power-weight ratio.
3.2.1.2.1.2	Dash Speed	Dash speed is typically time between 2 speeds (i.e. 10 to 30 MPH). 70 (75)MPH for 10 (20) min. Demands a very high power-weight ratio.
3.2.1.2.1.3	Sustained Low Speed	
3.2.1.2.1.4	Acceleration	Acceleration times specified will result in large engines (on the order of 250 hp for 15 sec accel and 450 hp for the goal of 10 sec accel). These engines will be very heavy (about 1,000 lbs). Are these acceleration limits necessary or is max speed more important? 0-30 MPH, 6 (4) Sec - Demands a very high power-weight ratio. 0-60 MPH, 15 (10) Sec - Demands a very high power-weight ratio.
3.2.1.2.1.5	Forward Motion	See temperature related comments above (3.2.1.2).
3.2.1.2.2	Braking	
3.2.1.2.2.1	Service Brakes	Braking times are aggressive and may be difficult to meet. Can they be relaxed? What is the possibility of using ABS for improved performance? Specify a time increment between the braking operations for the brake fade requirement.
3.2.1.2.2.2	Emergency Braking	
3.2.1.2.2.3	Parking Brake	
3.2.1.2.3	Tractive Effort	
3.2.1.2.3.1	Drawbar Pull	
3.2.1.2.3.2	Mobility Rating	Table 4 has a column for V80. Clarification is needed for the terrain type for this column, or a statement that it applies over all terrain.
3.2.1.2.3.3	Terrain's	
3.2.1.2.4	Obstacles	
3.2.1.2.4.1	Longitudinal Slopes	Typically shutdown of engine for not less than 1 minute and restart and continue up hill without roll-back is required.
3.2.1.2.4.2	Side Slopes	This will require a track width of about 60 inches, assuming a reasonable CG and roll center location, which will conflict with the overall width if it is reduced to 56 inches. This is in a static mode - the situation is worse dynamically or when gun firing conditions exist.
3.2.1.2.4.3	Vertical Step	
3.2.1.2.4.4	Fording	60" fording seems very unlikely, even with a fording kit. Should fording kit be added to OVE table 6.
3.2.1.2.5	Maneuverability	
3.2.1.2.5.1	Turning (Dynamic)	0.6 g acceleration would require a wide track for stability (in the region of 65 inches) and it is optimistic to hold the suspension roll below 5 degrees. Something may have to be relaxed if the vehicle width is reduced from the present 65 inches.
3.2.1.2.5.2	Turning (Static)	Increase the maximum turning radius from 25 feet to 30 feet in order to minimize the tire swept volume thereby enabling increased payload capacity and compliance with the breakover angle and acceleration (engine/motor fit between the front tires) requirements.
3.2.1.2.5.3	Vehicle Cone Index	

Paragraph Number	Paragraph Title	Comment
3.2.1.2.6	Interfaces	
3.2.1.2.6.1	Approach Angle	
3.2.1.2.6.2	Departure Angle	
3.2.1.2.6.3	Ground Clearance	
3.2.1.2.6.4	Break Over Angle	
3.2.1.2.7	Ride Quality	
3.2.1.2.7.1	Ride Limiting Speed	Why not reference MIL-STD-1472 whole body vibration requirements (5.8.4.1).
3.2.1.2.7.2	Obstacles	
3.2.1.2.8	Range	
3.2.1.2.9	Common Components	
3.2.1.2.9.1	Power Train	
3.2.1.2.9.1.1	Engine	Are we sure we want to limit ourselves to a diesel engine? "Fuel efficient" should be quantified.
3.2.1.2.9.1.2	Transmission	
3.2.1.2.9.1.3	STE/ICE	
3.2.1.2.9.1.4	Seals	
3.2.1.2.9.2	Suspension and Steering	
3.2.1.2.9.2.1	Wheels	Single Rim - Good. Should specify BEAD LOCK.
3.2.1.2.9.2.2	Tires	
3.2.1.2.9.2.3	Central Tire Inflation System	
3.2.1.2.9.2.4	Suspension Lockouts	
3.2.1.2.9.2.5	Steering	Forces not to exceed 5th % female capabilities (permissible increase in force with power drive failure?)
3.2.1.2.9.3	Windshield Wiper and Washers	
3.2.1.2.9.4	Bumpers	
3.2.1.2.9.5	Heater and Defroster	
3.2.1.2.9.6	Rear View Mirrors	
3.2.1.2.9.7	Electrical	
3.2.1.2.9.7.1	Electrical System	
3.2.1.2.9.7.2	Alternator	Caution: This may be unrealistic to have 100 amps at idle without over- speeding the alternator at high engine speeds (benchmark: BFV is 300 amps at elevated engine rpm (1600?)). A CV drive system may be required which is more costly, consider having a high idle capability to handle generating power requirements when stationary. May be able to offer more versatility by giving a power/noise level requirement keeping both options open to meet the power requirements with survivability requirements in mind.
3.2.1.2.9.7.3	Lighting	
3.2.1.2.9.7.4	Wiring	
3.2.1.2.9.7.5	Light Switch	
3.2.1.2.9.7.6	Ignition Switch	
3.2.1.2.9.8	Wheel Splash and Stone Throw Protection	
3.2.1.2.9.9	Secure Lighting	Should this be part of "Electrical System" above?
3.2.1.3	**Survivability**	
3.2.1.3.1	Acquisition Avoidance	
3.2.1.3.1.1	Signature Reduction	
3.2.1.3.1.1.1	Signature Spectral Bands	The wavelengths from 8-14 microns are typically only used in space applications with black backgrounds. Is there data which shows this to be useful in land based applications?
3.2.1.3.1.1.2	General Design Characteristics	
3.2.1.3.2	Visual Signature Reduction	
3.2.1.3.2.1	Luminance	
3.2.1.3.2.1.1	Surface Treatments	
3.2.1.3.2.2	Vertical Height	

Paragraph Number	Paragraph Title	Comment
3.2.1.3.2.3	Vehicle Silhouette	
3.2.1.3.2.4	Shape	
3.2.1.3.2.5	Glint	
3.2.1.3.2.6	Dust	
3.2.1.3.2.7	Smoke	
3.2.1.3.3	Near Infrared (IR) Signature Performance	Is this criteria realistic for a 2010 vehicle? Gen 3 will most likely be standard equipment by then.
3.2.1.3.3.1	Near Infrared Luminance	
3.2.1.3.4	Thermal Signature Performance	
3.2.1.3.4.1	Edge Effects	
3.2.1.3.4.2	Overall Vehicle	
3.2.1.3.4.3	Engine Top Deck	
3.2.1.3.4.4	Suspension	NA - Why NA? Wheels & hubs make plenty of heat.
3.2.1.3.4.5	Exhaust	NA - Why NA? The tail pipe and "plume" are discernible.
3.2.1.3.5	Acoustic Signature Reduction	
3.2.1.3.5.1	Stationary Requirement	
3.2.1.3.5.2	Moving Requirements	> 70 dB @ 50 ft - Too high a dB level.
3.2.1.3.5.3	Detection Range	
3.2.1.3.2	Hit Avoidance	NA - Why NA? One virtue of a high-performance vehicle with a high DASH SPEED is to depart rapidly. Paragraph number should be 3.2.1.3.6. Following paragraph numbers should also be corrected.
3.2.1.3.3	Penetration Avoidance	
3.2.1.3.3.1	Direct Fire Threats	7/62 @ 300 meters - Criteria seem unrealistic. At 300 meters hits are difficult and the weak rounds cited would not do much damage. Consider 100 meters, with more modern ammunition. Requirements driving armor configurations should perhaps allow for mission specific armor to be added to a basic lightweight armor configuration.
3.2.1.3.3.2	Indirect Fire Threats	NA - Why NA? Operators, especially Army Recom, say that ranging artillery fires are one of the greatest threats to scouts and flank security.
3.2.1.3.3.3	Mine Threats	Protection consistent with weight/mobility. - Seems to allow the next two requirements to be relaxed if weight or mobility requirements can't be met. This requirement wording does not constrain the design. Definition should be provided for the minimum requirement, such as probability of successful passage through a specified mine field without rendering the vehicle or onboard equipment inoperable. This would then allow a combination of mine detection and under-vehicle armor to meet the requirement.
3.2.1.3.3.3.1	Personnel Area	.50 (1.0) lbs TNT @ any wheel.
3.2.1.3.3.3.2	Fuel Tank(s)	.50 (1.0) lbs TNT @ any wheel.
3.2.1.3.4	Kill Avoidance	
3.2.1.3.4.1	Fire Prevention and Suppression	
3.2.1.3.4.1.1	System Design	
3.2.1.3.4.1.2	Design of Occupied Spaces	
3.2.1.3.4.1.3	Portable Fire Extinguisher	Should consider more than one fire extinguisher.
3.2.1.3.4.2	Nuclear, Biological, and Chemical (NBC)	
3.2.1.3.5	Common Components	
3.2.1.4	**Firepower**	
3.2.1.4.1	Target Acquisition	Too broad; change "all systems" to "systems". Need rough order of magnitude regarding volume, weight, power requirements of RST-V sensors.
3.2.1.4.2	Weapons	
3.2.1.4.2.1	Primary Weapon	Did not include STINGER (MANPAD), but did list several anti-armor weapons. SEALs carried STINGER in Desert Storm.

Paragraph Number	Paragraph Title	Comment
3.2.1.4.2.2	Secondary Weapon	M60 is 7.62mm; M240 is 5.56mm. Different ammo.
3.2.1.4.2.3	Individual Weapon	Reference table 3 to provide specifics.
3.2.1.4.3	Ammunition	M240 is 5.56, not 7.62
3.2.1.4.4	Common Components	
3.2.1.5	**Command, Control, Communications, Computers & Intelligence**	Should these systems be capable of tapping off of vehicle power when mounted within the vehicle, should they be able to recharge from the vehicle system?
3.2.1.5.1	Communication Equipment	Includes older models, not newer (SATCOM??) May want to carry amplifiers on vehicle that are not dismountable.
3.2.1.5.2	Internal Communication System (ICS)	VVS-1, VVS-2, and VVS-3 all compatible w/CVC Only VVS-2 works with digital comms.
3.2.1.5.3	Navigation Equipment	GPS batteries should charge off vehicle power. Include a "Whiskey Compass" for backup.
3.2.1.5.4	Common Components	
3.2.2	**System Capability Relationships**	
3.2.3	**External Interface Requirements**	
3.2.3.1	On Vehicle Equipment (OVE)	Incorporate table 6 with table 2. What about deep fording kit, doors, windows etc., winch, arctic kit?
3.2.3.2	Towing	
3.2.3.2.1	Tow Eyes	Should specify capacity.
3.2.3.2.2	Tow Pintle	
3.2.3.2.3	Electrical Connector	How about capability of interfacing with electric brakes on trailer also?
3.2.3.3	Power Distribution	The vehicle cannot be expected to operate in stealth mode using batteries only, if the main batteries are disconnected.
3.2.3.3.1	Equipment Compatibility	
3.2.3.3.1.1	Steady-State Voltage	
3.2.3.3.2	Slave Receptacle	Is there any other NSN'd item that is usable?
3.2.3.4	Fuel System	Consider specific safety requirements in 3.3.6 (fire resistant foam, spillover requirements, expansion for air transport).
3.2.3.4.1	Fuel/POLs	MIL-L-46167 Arctic oil.
3.2.3.4.2	Fueling	
3.2.3.4.3	Fuel Drain	
3.2.4	**Physical Characteristics**	
3.2.4.1	Protective Coatings	
3.2.4.1.1	Painting	
3.2.4.1.2	Corrosion Control	
3.2.4.2	Dimensions	Width: May change to 60 inches. Height: 59.6 in. at the aircraft side wall, not 66 in. Length: 250 in. is unreasonable. V22 will also carry other items, including vehicle crew, on aircraft seats.
3.2.4.2.1	Operational Dimensions	
3.2.4.3	Federal Motor Vehicle Safety Standards Compliance	Probably don't want an airbag because it might be triggered by rough terrain driving, such as climbing vertical steps. This one will take a little time/research to assure it is not picking up on passenger car type regulations which would inhibit functionality of the vehicle (incorporation of airbags, side impact protection, locks etc.)
3.2.5	**System Quality Factors**	
3.2.5.1	Reliability	
3.2.5.1.1	Mean Miles Between Operational Mission Failure	
3.2.5.2	Maintainability	
3.2.5.2.1	Mean-Time-To-Repair	5 hours at Intermediate level may be low dependent on tasks (engine teardown and repair) and if most easier tasks are pushed to the Org level

Paragraph Number	Paragraph Title	Comment
3.2.5.2.2	Maintenance Ratio	Does this include silent watch time? Engine idle?
3.2.5.2.3	Miles Between Preventative Maintenance	This spec should either specify which PM tasks apply or define operating environment i.e. "Under normal (non-hostile) environments".
3.2.5.2.4	Mean Time To Perform Preventive Maintenance	Objective of "8" seems to be an error.
3.2.5.3	Availability	
3.2.5.4	Additional Quality Factors	
3.2.6	**Environmental Conditions**	
3.2.6.1	Natural Environment	
3.2.6.1.1	Ambient Air Temperature	
3.2.6.1.1.1	Severe Cold Weather Operation	This can really drive many other requirements! Lots of impact if performance degradation is not permitted in cold etc.
3.2.6.1.1.2	Temperature Variation	
3.2.6.1.2	Solar Radiation	May need desert cammy net.
3.2.6.1.3	Humidity	
3.2.6.1.4	Moisture and Fungus	
3.2.6.1.5	Atmospheric Pressure	
3.2.6.1.6	Elevation	May wish to carry Oxygen bottles for USMC crew members at altitudes above 8000 ft.
3.2.6.1.7	Wind	Driving in 85 knot winds seems risky, especially if it is broadside and the vehicle width is reduced to 60 inches.
3.2.6.1.8	Other	Need clarification on "capable of operating" and the depth of "severe snow". This requirement is an important consideration in weighing wheels versus tracks or in having deployable tracks. Need weather kits & heaters.
3.2.6.2	Induced Environment	
3.2.6.2.1	Internal Acoustical Noise	
3.2.6.2.2	Loads	
3.2.6.2.2.1	Accidental Loads	
3.2.6.2.2.2	Transportation Loads	
3.2.6.2.2.3	Towing, Lifting and Transport Loads	Towing requirements not listed here? Should state towing for a minimum number of miles at a maximum speed without damage. Generally these types of requirements limit or prohibit preparation time prior to towing. (or in paragraph 3.2.3.2).
3.2.6.2.3	Shock	Permit tailoring of the spec?
3.2.6.2.4	Vibration	
3.2.6.2.5	Explosive Atmosphere	
3.2.6.3	Operating Profile	
3.2.6.4	Prepositioning	
3.2.7	**Transportability**	
3.2.7.1	Amphibious Shipping	
3.2.7.2	Maritime Prepositioning Ships	
3.2.7.3	Rail Transportation	
3.2.7.4	Highway Transportation	
3.2.7.5	Air Transportation	
3.2.7.5.1	Fixed Wing	
3.2.7.5.2	Rotary Wing	
3.2.7.5.3	Crew Ingress/Egress	See 3.3.6.2 for more stringent requirement. Aircraft loadmaster will require access to rear of cabin, for safety of flight.
3.2.7.5.4	Vehicle Ingress/Egress	
3.2.7.6	Air Drop	
3.2.8	**Flexibility and Expansion**	
3.2.8.1	Modular Subsystems and Components	Applicable subsystems should be defined (Does this include power train components).
3.2.8.2	Growth	"Reasonable growth" should be quantified.
3.2.8.3	Special Kits	Storage and permissible degradation factors for these kits is not included throughout the spec.
3.2.8.3.1	Winch Kit	

Paragraph Number	Paragraph Title	Comment
3.2.8.3.2	Modular Armor Kit	Has spec been determined?
3.2.8.3.3	Arctic Kit	
3.2.8.3.4	Deep Water Fording Kit	The spec. originated for large trucks and may not be appropriate for RST-V.
3.2.8.3.5	Soft Top Kit	Will this be carried as aux equipment (stowed), or will it be standard/installed on the vehicle?
3.2.9	**Portability**	
3.2.9.1	Lifting Eyes and Tiedowns	
3.3	DESIGN AND CONSTRUCTION	
3.3.1	**Materials**	
3.3.1.1	Toxic Products and Formulations	
3.3.1.1.1	Toxic Fumes	
3.3.1.2	Metric System	
3.3.2	**Electromagnetic Radiation**	
3.3.2.1	Electromagnetic Interference/ Electromagnetic Compatibility	
3.3.3	**Nameplates and Product Marking**	
3.3.4	**Workmanship**	
3.3.5	**Interchangeability**	
3.3.6	**Safety**	If this is to include program issues then reference to MIL-STD-882 and it's individual tasking should be called out as applicable
3.3.6.1	Impact	
3.3.6.1.1	Restraining Devices	
3.3.6.1.2	Padding	
3.3.6.1.3	Roll-Over Protection	
3.3.6.2	Emergency Egress	Are additional equipment's allowed to degrade this evacuation time, i.e. transparent armor sides etc. If so is there a requirement for evacuation times with these accessories in place?
3.3.6.2.1	Crew Evacuation	
3.3.7	**Human Engineering**	
3.3.7.1	Crew and Personnel	
3.3.7.1.1	Vision	
3.3.7.2	Controls, Instruments, Displays, and Lights	
3.3.7.3	Stowage Accessibility	
3.3.7.4	Ingress/Egress Aids	
3.3.8	**Nuclear Control**	
3.3.9	**System Security**	You may wish to make this applicable for RST-V variants that carry high tech sensors.
3.3.10	**Government Furnished Property Usage**	
3.3.11	**Computer Resource Reserve Capacity**	
3.4	DOCUMENTATION	
3.5	LOGISTICS	
3.5.1	**Maintenance Planning**	
3.5.1.1	Two-Level Maintenance	
3.5.1.2	Partitioning (Functional Modularity)	
3.5.2	**Support and Test Equipment**	
3.5.2.1	Support Equipment	
3.5.2.2	Test Points	
3.5.2.3	Tools	
3.5.2.4	Design for Discard	

Paragraph Number	Paragraph Title	Comment
3.5.3	**Supply Support**	
3.5.3.1	Supply System Requirements	
3.5.3.2	Source, Maintenance, and Recoverability (SMR) Codes	
3.5.3.3	Consumable and Bulk Items	
3.5.4	**Packaging and Handling**	
3.5.4.1	Preparation	
3.5.4.2	Packaging	
3.5.4.3	Special Equipment	
3.5.4.4	Preservation, Packaging, and Packing	
3.5.4.5	Marking for Shipment	
3.5.5	**Facilities**	
3.5.5.1	Impact on Existing Support Facilities	
3.5.5.1.1	First Echelon Maintenance Facilities	
3.5.5.1.2	Second and Third Echelon Maintenance Facilities	
3.5.5.1.3	Fourth and Fifth Echelon Maintenance Facilities	
3.6	**PERSONNEL AND TRAINING**	
3.6.1	Personnel	
3.6.2	Training	
3.6.2.1	Operator Training	
3.6.2.2	Maintenance Training	
3.7	**CHARACTERISTICS OF SUBORDINATE ELEMENTS**	
3.7.1	Mobility Subsystem	
3.7.2	Survivability Subsystem	
3.7.3	Firepower Subsystem	
3.7.4	C4I Subsystem	
3.8	**PRECEDENCE**	
3.8.1	Life Cycle Cost and Performance	
3.8.2	Life Cycle Cost (LCC) Elements	
3.8.2.1	Operation and Support (O&S)	
3.8.2.2	Average Unit Rollaway Cost (AURC)	Does this include weapons? Radios? Sensors? Or is this the price of the basic mobility platform?
3.9	**QUALIFICATION**	
3.10	**STANDARD SAMPLE**	
3.11	**PREPRODUCTION SAMPLE**	
4.	**QUALITY ASSURANCE PROVISIONS**	
4.1	**RESPONSIBILITY FOR INSPECTION**	
4.1.1	Inspection	
4.1.2	Analysis	
4.1.3	Demonstration	
4.1.4	Modeling and Simulation	
4.1.4.1	Modeling	
4.1.4.2	Simulation	
4.1.5	Testing	
4.2	**SPECIAL TESTS AND EXAMINATIONS**	
4.2.1	Object Level	

Paragraph Number	Paragraph Title	Comment
4.2.1.1	Component	
4.2.1.2	Subsystem	
4.2.1.3	System	
4.2.2	Model Description	
4.2.2.1	Virtual Model	
4.2.2.2	Physical Scale Model	
4.2.2.3	Physical Full Scale Model	
4.3	**REQUIREMENTS CROSS REFERENCE**	
4.4	**PROCESS**	
4.4.1	Duration	
4.4.2	Technique	
4.4.3	Derived Data	
4.4.4	Measured Data	
5.	**PREPARATION FOR DELIVERY**	
6.	**NOTES**	
6.1	**INTENDED USE**	
6.1.1	Missions	
6.1.1.1	Stability Operations	
6.1.1.2	Limited Objective Operations	
6.1.1.3	Conventional Combat Operations	Does USMC only want an amphibious V-22 capable vehicle?
6.1.2	Threat	
Missing	Missing	Driver field of view is currently unspecified. It probably should be specified.

54

APPENDIX B

Critical Parameters Matrix Comments

Lockheed Martin Defense Systems
100 Plastics Avenue
Pittsfield, MA 01201
October 15, 1996

Naval Surface Warfare Center CD MCPO
Carderock Division Headquarters
Code 2020
Bethesda, MD 20084-5000
Attn: Jeffrey A. Bradel

Subject: LMDS-Chenowth Comments to Carderock Critical Parameters Matrix

Reference: RSTA-V Concept Study In-Process Review #1 - Action Item #3

Enclosures: Filled Out Critical Parameters Matrices

A number of individuals from our LMDS-Chenowth project team have reviewed, discussed, and filled out the critical parameters matrix (referred to as Survey) provided by Carderock at the RSTA-V Concept Study In-process Review #1. Participants included systems, safety, and field support engineers. A summary of our findings follows.

General comments:

The survey is valuable. Filling it out forces you to define your priorities. As soon as survey participants complete the form, they should be interviewed to ensure the rationale for their priorities is fully understood. This could be an excellent approach for identifying specific user and developer needs.

Rationale for weightings should be documented. Suggest adding a "Rationale" column to the survey to help ensure capturing participants reasons for assigning different weightings.

It may be appropriate to have separate survey forms. Each form would be tailored to a mission area of interest (RSTA-V, LSV, Personnel, Litters/logistics). This could provide for more accurate survey conclusions but would work better if the survey forms only included the detailed requirements that were most closely associated with the mission of interest. Also, this type of survey should only be done after top level vehicle and subsystem concepts have been defined for the mission area of interest.

Prior to the definition of mission specific vehicle and subsystem concepts, the present survey form, which is of a more general nature, is more appropriate. By knowing the background of survey participants, the general survey form provides for determining what is most important to particular users or particular developers. Also, by including parameters like Average Unit

Rollaway Cost (presently not included), presently assumed differences between user and developer communities could be verified.

Top Level Filters:

A minimum set of mandatory requirements will help to focus developer activities and could reduce development costs (if other specification requirements are not too stringent or defined as goals (non-mandatory)).

If survey participants are asked to identify any missing mandatory requirements (present survey instructions don't specifically request this), a different perspective on priorities might emerge.

Candidate additional top level, mandatory requirements include Range, Forward Speed, Average Unit Rollaway Cost, and Maximum Speed at RMS Course (Reliability/Durability driver that should include duration/duty cycle requirements).

Consider eliminating some Transportability modes since the V-22 is a worst case for certain parameters.

Weighting of the Four Functional Headings:

Survey participant's functional areas and weightings are shown in Attachment A. Weightings were established from three perspectives (LSV, RSTA-V, and General). As shown, not all participants provided all three perspectives.

Weighting of the Individual Requirements:

Survey participant's functional areas and weightings are included in Enclosures one through six.

Survey Participant	Representing
Jim Biancolo	LMDS Land Combat Systems Engineering
Steve Brown	LMDS Land Combat Systems Engineering
Jim Gibbons	LMDS Safety Engineering
Ange Castellano	LMDS Field Support Engineering
Chris Johnson	Chenowth - Mission/Vehicle Capabilities Analysis

Present method of making the sum of the sub-values total the subcategory weight within each overall category is somewhat cumbersome. Participant is spending time dealing with math and not as much time may be focused on relative weightings. Suggest using rounded percentages as shown in marked-up sample weighting section (Attachment B). Enclosures four and five include surveys that apply this approach. If this approach is used, a spreadsheet could be setup to perform the math necessary to evaluate participant's percentage inputs.

Enclosure three has been marked up to identify apparent incorrect shadings of some cells.

It is unclear whether the MK 93 Dual Mount entry (Firepower - Survey page 1) is a note or an entry to be weighted.

Signature Reduction entry (Survivability - Survey page 2) appears to be redundant. Also, why not include Radio Frequency Signature Performance (since it is listed in Specification paragraph 3.2.1.3.1.1.1 - Signature Spectral Bands)?

Mean Time to Perform Preventative Maintenance (Criteria Descriptions - Survey page 3) appears to have an error since its objective value is less demanding (8 hours) than the stated requirement value (6 hours).

Consider replacing Availability (Supportability - Survey page 1) with Logistic Delay Time and Administrative Delay Time since the other elements of Availability covered by the already included Reliability and Maintainability parameters.

Hope this is of some help.

Jim B.

Jim Biancolo
LMDS Land Combat Systems Engineering

60

Carderock Critical Parameter Matrix

LMDS-Chenowth Evaluation

Weight Values for General Headings

LSV

Function	Survey Participant					
	Jim Biancolo (1)	Steve Brown (1)	Joe Rubin (1)	Jim Gibbons (2)	Ange Castellano (3)	Chris Johnson (4)
Lethality	.40	.35	.30	.40	.30	-
Supportability	.20	.10	.20	.20	.20	-
Survivability	.10	.25	.25	.10	.20	-
Mobility	.30	.30	.25	.30	.30	-

RSTA-V

Function	Survey Participant					
	Jim Biancolo (1)	Steve Brown (1)	Joe Rubin (1)	Jim Gibbons (2)	Ange Castellano (3)	Chris Johnson (4)
Lethality	.10	.25	.20	.20	.15	-
Supportability	.20	.15	.20	.20	.25	-
Survivability	.40	.30	.30	.40	.25	-
Mobility	.30	.30	.30	.20	.35	-

General

Function	Survey Participant					
	Jim Biancolo (1)	Steve Brown (1)	Joe Rubin (1)	Jim Gibbons (2)	Ange Castellano (3)	Chris Johnson (4)
Lethality	.20	.20	.25	.35	-	.14
Supportability	.30	.10	.20	.15	-	.08
Survivability	.20	.30	.25	.20	-	.18
Mobility	.30	.40	.30	.30	-	.60

(1) LMDS Land Combat Systems Engineering
(2) LMDS Safety Engineering
(3) LMDS Field Support Engineering
(User Perspective)
(4) Chenowth - Mission/Vehicle Capabilities Analysis

PROCEDURES FOR COMPLETION OF CRITICAL PARAMETERS MATRIX

1. Examine the enclosed criteria evaluation sheet and criteria descriptions.

2. Determine and comment if the Top Level filters are mandatory requirements.

3. Based on your experience, assign a weight value to the four general functional headings of Lethality, Supportability, Survivability, Mobility. The sum of these four values should equal 1.00.

4. Next, assign weights to the individual requirements under each functional category (i.e. Lethality). The sum of these sub-values should total the overall category weight. See below for an example of this procedure.

CRITERIA FOR EVALUATION

Sample Weighting Section

LETHALITY = .21		Weight	
	70%		
Firepower	0.140		
Primary Weapon (M-2 .50 cal / MK-19 40mm Grenade Launcher)		0.060	40%
MK-93 Dual Mount for Primary Weapons			
Secondary Weapon (M-60E3/M240)		0.040	30%
Individual Weapon		0.010	10%
Ammunition		0.030	20%
Command, Control, Comm, Computers & Intel 30%	0.070		
Communication Equipment		0.010	15%
Internal Communication System (ICS)		0.010	15%
Navigation Equipment		0.050	70%
Total	0.210	~~0.210~~	NA
	100%		

Enclosure 1

Jim Biancolo
LMDS Land Combat Systems Engineering

LSV Evaluation

CRITERIA FOR LSV EVALUATION

LSV

* TOP LEVEL FILTER (Thresholds)	Yes	No
ADD ? Weight		
Gross Vehicle Weight (GVW) 8,000 lb	✓	
Payload 3,000 lb	✓	
Dimensions		
Operational Dimensions (V-22 compatible) WORST CASE ?	✓	
Transportability		✓
Amphibious Shipping (LHA, LHD, LSD, LSD(CV), LPD)		
Maritime Prepositioning Ships (MPS)		
Rail Transportation		
Highway Transportation		
Fixed wing (C-130 and larger)		
Rotary Wing (V-22 and CH-53E internal, UH-60A, CH-47C CH-47D, CH-53D, V-22 external)	✓	
* Crew Ingress/Egress	✓	
* Vehicle Ingress/Egress	✓	

LETHALITY = .4	Weight	
Firepower	.25	
? Primary Weapon (M-2 .50 cal / MK-19 40mm Grenade Launcher)		.08
MK-93 Dual Mount for Primary Weapons		0
Secondary Weapon (M-60E3/M240)		.05
Individual Weapon		.04
Ammunition		.08
Command, Control, Comm, Computers & Intel	.15	
Communication Equipment		.06
Internal Communication System (ICS)		.06
Navigation Equipment		.03
Total	.4	.4

SUPPORTABILITY = .2	Weight	
Reliability	.1	
* Mean Miles Between Opn Mission Failure		.1
Maintainability	.1	
* Mean-Time-To-Repair		.05
* Maintenance Ratio		0
* Miles Between Preventative Maintenance		.05
* Mean Time To Perform Preventative Maintenance		0
Availability	0	
Total	.2	.2

* FORWARD SPEED

RANGE

MAX SPEED AT RMS COURSE (WITH, DURATION & DUTY CYCLE)
— RELIABILITY/DURABILITY DRIVER

AVERAGE UNIT ROLLAWAY COST

64

SURVIVABILITY = .1	Weight	
Acquisition Avoidance	.04	
~~Signature Reduction~~		
Visual Signature Reduction		.013
Near Infrared (IR) Signature Performance		.007
Thermal Signature Performance		.007
Acoustic Signature Performance		.013
Hit Avoidance	.02	
Penetration Avoidance	.02	
Direct Fire Threats		.01
Indirect Fire Threats		0
Mine Threats		.01
Kill Avoidance	.02	
Fire Prevention and Suppression		.02
Nuclear, Biological, and Chemical (NBC)		0
Total	.1	.1

MOBILITY = .3	Weight	
Speed	.05	
Forward Speed		.02
Dash Speed		.02
Sustained Low Speed		0
Acceleration		.01
Forward Motion		0
Braking	.02	
Service brakes		.02
Obstacles	.05	
Longitudinal Slopes		.01
Side slopes		.02
Vertical Step		0
Fording		.02
Maneuverability	.02	
* Turning (Static)		
Interfaces	.04	
Approach Angle		.01
Departure Angle		.01
Ground Clearance		.01
Break Over Angle		.01
Ride Quality	.035	
Ride Limiting speed		.025
Obstacles		.010
Range	.05	
Suspension / Steering	.035	
Central Tire Inflation System		.015
* Run Flat Capability		.020
Total	.3	.3

CRITERIA DESCRIPTIONS

Crew Ingress/Egress: The vehicle shall incorporate ingress/egress paths to the aircraft personnel/cargo compartment while the vehicle is loaded aboard a fixed-wing or rotary-wing aircraft (i.e. removable/stowable windshield, a folding windshield, or other means).

Vehicle Ingress/Egress: On landing, the vehicle shall be clear of the aircraft and achieve a "guns up" and ready to fire status within 15 seconds after the ramp is fully lowered. On take-off, the vehicle shall be loaded into the aircraft and achieve a "flight ready" status within 2 minutes after starting to ascend the ramp.

Mean Miles Between Operational Mission Failure: The Mean Miles Between Operational Mission Failure (MMBOMF) shall be 2000 mi (3219 km) or greater. It is an objective that the MMBOMF shall be 3000 mi (4828 km).

Mean-Time-To-Repair: The Mean-Time-To-Repair (MTTR) at the organizational level (1st and 2nd echelon) shall be 3.0 man-hours or less; at the intermediate level (3rd and 4th echelon) the MTTR shall be 5.0 man-hours or less. MTTR is the sum of corrective maintenance time at any specific level of repair, divided by the total number of failures repaired during the particular interval.

Maintenance Ratio: The Maintenance Ratio of the vehicle shall be .16 man-hours or less of maintenance (preventative and corrective) per hour of operation. The Maintenance ratio does not include PMCS.

Miles between Preventative Maintenance. The miles between Preventative Maintenance (MBPM) shall be no less than 3000 mi (4828 km) or 6 months. It is an objective that the MBPM shall be 4000 mi (6437 km) or 8 months.

Mean Time To Perform Preventative Maintenance. The Mean Time To Perform Preventative Maintenance (MTTPPM) shall be no greater than 6 hours. It is an objective that the MTTPPM shall be 8 hours. ERROR ?

Turning (Static): The vehicle static turning radius shall not exceed 25ft (7.62m) curb to curb, and the vehicle shall complete the turn from a static position in less than 9.5 seconds. It is an objective that the vehicle turning radius shall not exceed 20 ft (6.1m) curb to curb, and that the vehicle complete the turn from a static position in less than 8 seconds.

Run Flat Capability: The tires shall have a threshold run flat capability of 30 miles at 30 mph (48 km at 48 kph) on a hard surface road, after loss of air pressure in any two tires.

66

Enclosure 2

Steve Brown
LMDS Land Combat Systems Engineering

LSV Evaluation

LSV

TOP LEVEL FILTER (Thresholds)	Yes	No
Weight	✓	
Gross Vehicle Weight (GVW) 8,000 lb	✓	
Payload 3,000 lb	✓	
Dimensions		
Operational Dimensions (V-22 compatible)		✓
Transportability	✓	
Amphibious Shipping (LHA, LHD, LSD, LSD(CV), LPD)	✓	
Maritime Prepositioning Ships (MPS)	✓	
Rail Transportation	✓	
Highway Transportation	✓	
Fixed wing (C-130 and larger)	✓	
Rotary Wing (V-22 and CH-53E internal, UH-60A, CH-47C	✓	
CH-47D, CH-53D, V-22 external)	✓	
* Crew Ingress/Egress	✓	
* Vehicle Ingress/Egress	✓	

LETHALITY = .35	Weight	
Firepower	.25	
Primary Weapon (M-2 .50 cal / MK-19 40mm Grenade Launcher)		.10
MK-93 Dual Mount for Primary Weapons		
Secondary Weapon (M-60E3/M240)		.075
Individual Weapon		.02
Ammunition		.055
Command, Control, Comm, Computers & Intel	0.10	
Communication Equipment		.05
Internal Communication System (ICS)		.02
Navigation Equipment		.03
Total	.35	.35

SUPPORTABILITY = 0.1	Weight	
Reliability	.05	
* Mean Miles Between Opn Mission Failure		.05
Maintainability	.03	
* Mean-Time-To-Repair		.01
* Maintenance Ratio		.005
* Miles Between Preventative Maintenance		.005
* Mean Time To Perform Preventative Maintenance		.01
Availability	.02	
Total	.10	.10

Steven J Brown
10/10/96
LSV Survey

68

LSV

SURVIVABILITY = 0.25	Weight	
Acquisition Avoidance	.04	
Signature Reduction		
Visual Signature Reduction		.01
Near Infrared (IR) Signature Performance		.01
Thermal Signature Performance		.01
Acoustic Signature Performance		.01
Hit Avoidance	.055	.055
Penetration Avoidance	.075	
Direct Fire Threats		.035
Indirect Fire Threats		.015
Mine Threats		.025
Kill Avoidance	.08	
Fire Prevention and Suppression		.04
Nuclear, Biological, and Chemical (NBC)		.04
Total	.25	.25

MOBILITY = 0.3	Weight		
Speed	0.065		
Forward Speed		.01	
Dash Speed		.025	
Sustained Low Speed		.005	
Acceleration		.02	
Forward Motion		.005	
Braking	0.015		
Service brakes		.015	
Obstacles	0.055		
Longitudinal Slopes		.025	
Side slopes		.02	
Vertical Step		.0025	
Fording		.0075	
Maneuverability	0.015		
* Turning (Static)		.015	
Interfaces	0.05		
Approach Angle		.0075	
Departure Angle		.0075	
Ground Clearance		.03	
Break Over Angle		.005	
Ride Quality	0.04		
Ride Limiting speed		.025	
Obstacles		.015	
Range	0.02		
Suspension / Steering	0.04		
Central Tire Inflation System		~~.02~~	.03
* Run Flat Capability		~~.02~~	.01
Total	0.30	.30	

Steven J Brown
10/10/96
LSV Survey

Enclosure 3

Steve Brown
LMDS Land Combat Systems Engineering

General Evaluation

70

GENERAL

TOP LEVEL FILTER (Thresholds)	Yes	No
Weight		
Gross Vehicle Weight (GVW) 8,000 lb		✓
Payload 3,000 lb	✓	
Dimensions		
Operational Dimensions (V-22 compatible)	✓	
Transportability		
Amphibious Shipping (LHA, LHD, LSD, LSD(CV), LPD)		
Maritime Prepositioning Ships (MPS)		
Rail Transportation		
Highway Transportation		
Fixed wing (C-130 and larger)		
Rotary Wing (V-22 and CH-53E internal, UH-60A, CH-47C		
CH-47D, CH-53D, V-22 external)		
* Crew Ingress/Egress		
* Vehicle Ingress/Egress	✓	

LETHALITY = .2	Weight	
Firepower	.15	
Primary Weapon (M-2 .50 cal / MK-19 40mm Grenade Launcher)		.05
MK-93 Dual Mount for Primary Weapons		
Secondary Weapon (M-60E3/M240)		.03
Individual Weapon		.02
Ammunition		.05
Command, Control, Comm, Computers & Intel	.05	
Communication Equipment		.03
Internal Communication System (ICS)		.01
Navigation Equipment		.01
Total	.20	.20

SUPPORTABILITY = .1	Weight		
Reliability	.05		.05
* Mean Miles Between Opn Mission Failure			
Maintainability	.03		
* Mean-Time-To-Repair		.01	
* Maintenance Ratio		.005	
* Miles Between Preventative Maintenance		.005	
* Mean Time To Perform Preventative Maintenance		.01	
Availability	.02		.02
Total	.10	.10	

Steven J Brown
10/3/96

CRITERIA FOR ~~LSV~~ EVALUATION

GENERAL

SURVIVABILITY = .3	Weight		
Acquisition Avoidance	.12		
Signature Reduction			
Visual Signature Reduction		.02	
Near Infrared (IR) Signature Performance		.04	
Thermal Signature Performance		.04	
Acoustic Signature Performance		.02	
Hit Avoidance	.08		.08
Penetration Avoidance	.06		
Direct Fire Threats		.03	
Indirect Fire Threats		.01	
Mine Threats		.02	
Kill Avoidance	.04		
Fire Prevention and Suppression			.025
Nuclear, Biological, and Chemical (NBC)			.015
Total	.30	.30	

MOBILITY = .4	Weight	
Speed	.08	
Forward Speed		.01
Dash Speed		.03
Sustained Low Speed		.005
Acceleration		.03
Forward Motion		.005
Braking	.015	
Service brakes		.015
Obstacles	.06	
Longitudinal Slopes		.03
Side slopes		.02
Vertical Step		.0025
Fording		.0075
Maneuverability	.025	
* Turning (Static)		
Interfaces	.07	
Approach Angle		.02
Departure Angle		.01
Ground Clearance		.035
Break Over Angle		.005
Ride Quality	.055	
Ride Limiting speed		~~.3~~ .035
Obstacles		.02
Range	.025	
Suspension / Steering	.07	
Central Tire Inflation System		.075
* Run Flat Capability		.025
Total	.4	.4

Steven J Brown
10/3/96

72

Enclosure 4

Jim Gibbons
LMDS Safety Engineering

LSV Evaluation
Done with recommended "Percentage Approach"

LSV

TOP LEVEL FILTER (Thresholds)	Yes	No
Weight		
Gross Vehicle Weight (GVW) 8,000 lb	✓	
Payload 3,000 lb		✓
Dimensions		
Operational Dimensions (V-22 compatible)		✓
Transportability		
Amphibious Shipping (LHA, LHD, LSD, LSD(CV), LPD)	✓	
Maritime Prepositioning Ships (MPS)	✓	
Rail Transportation	✓	
Highway Transportation	✓	
Fixed wing (C-130 and larger)	✓	
Rotary Wing (V-22 and CH-53E internal, UH-60A, CH-47C	✓	
CH-47D, CH-53D, V-22 external)		
* Crew Ingress/Egress	✓	
* Vehicle Ingress/Egress	✓	

LETHALITY = 40	Weight	
Firepower	60	
Primary Weapon (M-2 .50 cal / MK-19 40mm Grenade Launcher)		40
MK-93 Dual Mount for Primary Weapons		
Secondary Weapon (M-60E3/M240)		10
Individual Weapon		25
Ammunition		25
Command, Control, Comm, Computers & Intel	40	
Communication Equipment		40
Internal Communication System (ICS)		30
Navigation Equipment		30
Total	100	

SUPPORTABILITY = 20	Weight	
Reliability	35	
* Mean Miles Between Opn Mission Failure		
Maintainability	15	
* Mean-Time-To-Repair		10
* Maintenance Ratio		10
* Miles Between Preventative Maintenance		10
* Mean Time To Perform Preventative Maintenance		70
Availability	50	
Total	100	

JMD.

9/10/96

LSV

SURVIVABILITY = 10	Weight	
Acquisition Avoidance	15	
~~Signature Reduction~~		—
Visual Signature Reduction		15
Near Infrared (IR) Signature Performance		15
Thermal Signature Performance		5
Acoustic Signature Performance		65
Hit Avoidance	25	
Penetration Avoidance	40	
Direct Fire Threats		35
Indirect Fire Threats		50
Mine Threats		15
Kill Avoidance	20	
Fire Prevention and Suppression		60
Nuclear, Biological, and Chemical (NBC)		40
Total	100	

MOBILITY = 30	Weight	
Speed	20	
Forward Speed		30
Dash Speed		20
Sustained Low Speed		10
Acceleration		30
Forward Motion		10
Braking	15	
Service brakes		—
Obstacles	15	
Longitudinal Slopes		30
Side slopes		30
Vertical Step		20
Fording		20
Maneuverability	10	
* Turning (Static)		—
Interfaces	5	
Approach Angle		10
Departure Angle		10
Ground Clearance		60
Break Over Angle		20
Ride Quality	15	
Ride Limiting speed		50
Obstacles		50
Range	10	
Suspension / Steering	10	
Central Tire Inflation System		40
* Run Flat Capability		60
Total	100	

JMG.

75

Enclosure 5

Ange Castellano
Field Support Engineering

LSV Evaluation
Done with recommended "Percentage Approach"

76

CRITERIA FOR LSV EVALUATION

Ange Castellano
+ Bob Repulinski

TOP LEVEL FILTER (Thresholds)	Yes	No
Weight		
Gross Vehicle Weight (GVW) 8,000 lb	✓	
Payload 3,000 lb	✓	
Dimensions		
Operational Dimensions (V-22 compatible)	✓	
Transportability		
Amphibious Shipping (LHA, LHD, LSD, LSD(CV), LPD)	✓	
Maritime Prepositioning Ships (MPS)	✓	
Rail Transportation	✓	
Highway Transportation	✓	
Fixed wing (C-130 and larger)	✓	
Rotary Wing (V-22 and CH-53E internal, UH-60A, CH-47C	✓	
CH-47D, CH-53D, V-22 external)	✓	
* Crew Ingress/Egress	✓	
* Vehicle Ingress/Egress	✓	

* Dependent on mission

LETHALITY = 30	Weight	
Firepower	67	
Primary Weapon (M-2 .50 cal / MK-19 40mm Grenade Launcher)		30
MK-93 Dual Mount for Primary Weapons		10
Secondary Weapon (M-60E3/M240)		20
Individual Weapon		10
Ammunition		30
Command, Control, Comm, Computers & Intel	33	
Communication Equipment		25
Internal Communication System (ICS)		40
Navigation Equipment		35
Total		

SUPPORTABILITY = 20	Weight	
Reliability	45	
* Mean Miles Between Opn Mission Failure		
Maintainability	45	
* Mean-Time-To-Repair		50
* Maintenance Ratio		5
* Miles Between Preventative Maintenance		30
* Mean Time To Perform Preventative Maintenance		15
Availability	10	
Total		

A_o which includes Logistics Delay Time + ADMIN Delay Time

% used

But Exclude Reliability + Maintainability Factor SINCE INCLUDED ABOVE

CRITERIA FOR LSV EVALUATION

SURVIVABILITY = 20	Weight	
Acquisition Avoidance	50	
Signature Reduction		25
Visual Signature Reduction		20
Near Infrared (IR) Signature Performance		15
Thermal Signature Performance		15
Acoustic Signature Performance		25
Hit Avoidance	25	
Penetration Avoidance	5	
Direct Fire Threats		30
Indirect Fire Threats		30
Mine Threats		40
Kill Avoidance	20	
Fire Prevention and Suppression	50	
Nuclear, Biological, and Chemical (NBC)	50	
Total		

MOBILITY = 30	Weight	
Speed	15	
Forward Speed		20
Dash Speed		30
Sustained Low Speed		10
Acceleration		30
Forward Motion ?		10
Braking	10	
Service brakes		10
Obstacles	20	
Longitudinal Slopes		25
Side slopes		25
Vertical Step		25
Fording		25
Maneuverability	15	
* Turning (Static)		
Interfaces	20	
Approach Angle		25
Departure Angle		25
Ground Clearance		25
Break Over Angle		25
Ride Quality	6	
Ride Limiting speed		60
Obstacles		40
Range	4	
Suspension / Steering	10	
Central Tire Inflation System		40
* Run Flat Capability		60
Total		

9/10/96

78

Enclosure 6

Chris Johnson
Chenowth - Mission/Vehicle Capabilities Analysis

General Evaluation

CRITICAL PARAMETERS MATRIX
NSWC Carderock RSTA-V Study
CW Johnson Response

4 October 1996

NSWC Carderock generated to assign weights to general functions as well as individual capabilities and requirements for the RSTA-V vehicle.

The matrix will be used as a questionaire to USMC, SOCOM and other prospective users. Also, the contractors (LMDS-CC, GDLS and RMM) will fill it out for comparison sake.

CATEGORY	CW JOHNSON YES	CW JOHNSON NO
TOP LEVEL FILTER (Thresholds)	YES	NO
Weight		
Gross Vehicle Weight (GVW) 8000 lb	X	
Payload 3000 lb	X	
Dimensions		
Operational Dimensions (V-22 Compatible)	X	
Transportability		
Amphibious Shipping (LHA, LHD, LSD, LDS(CV), LPD)	X	
Maritime Prepositioning Ships (MPS)	X	
Rail Transportation	X	
Highway Transportation	X	
Fixed Wing (C-130 & larger)	X	
Rotary Wing (V-22 and CH53E internal, UH-60	X	
CH-47C, CH-47D CH=53D, V-22 external)	X	
* Crew Ingress / Egress	X	
* Vehicle Ingress / Egress	X	

LETHALITY = 0.14	WEIGHT	
Firepower	0.100	
Primary Weapon (M2 .50 Cal / MK-19 40mm)		0.040
. MK-93 Dual Mount for Primary Weapons		0.005
Secondary Weapon (M60E3/M240G)		0.030
Individual Weapon		0.005
Ammunition		0.020
Command, Control, Comm, Computers & Intel	0.040	
Communications Equipment		0.020
Internal Communication System (ICS)		0.005
Navigation Equipment		0.015
Total	0.140	0.140

SUPPORTABILITY = 0.08	WEIGHT	
Reliability	0.010	
* Mean Miles Between Opn Mission Failure		0.010
Maintainability	0.060	
* Mean-Time-To-Repair		0.010
* Maintenance Ratio		0.010
* Miles Between Preventive Maintenance		0.020
* Mean Time to Perform Preventive Maintenance		0.020
Availability	0.010	0.010
Total	0.080	0.080

80

CRITICAL PARAMETERS MATRIX
NSWC Carderock RSTA-V Study
CW Johnson Response

4 October 1996

SURVIVABILITY = 0.18		WEIGHT	
Acquisition Avoidance		0.085	
Signatue Reduction			0.020
Visual Signature Reduction			0.015
Near Infrared (IR) Signature Performance			0.015
Thermal Signature Performance			0.015
Acoustic Signature Performance			0.020
Hit Avoidance		0.020	0.020
Penetration Avoidance		0.050	
Direct Fire Threats			0.020
Indirect Fire Threats			0.015
Mine Threats			0.015
Kill Avoidance		0.025	
Fire Prevention and Suppression			0.020
Nuclear, Biological and Chemical (NBC)			0.005
	Total	0.180	0.180

MOBILITY = 0.60		WEIGHT	
Speed .		0.215	
Forward Speed			0.040
Dash Speed			0.080
Sustained Low Speed			0.010
Acceleration			0.080
Forward Motion			0.005
Braking		0.020	
Service Brakes			0.020
Obstacles		0.105	
Longitudinal Slopes			0.025
Slide Slopes			0.040
Vertical Step			0.020
Fording			0.020
Maneuverability		0.020	
* Turning (Static)			0.020
Interfaces		0.110	
Approach Angle			0.030
Departure Angle			0.030
Ground Clearance			0.030
Break Over Angle			0.020
Ride Quality		0.070	
Ride Limiting Speed			0.040
Obstacles			0.030
Range		0.020	0.020
Suspension / Steering		0.040	
Central Tire Inflation System			0.020
* Run Flat Capability			0.020
	Total	0.600	0.600

APPENDIX C

User Topics

Questions for a RST-V Vehicle User

Requirements

1) Which vehicle capabilities are most important?

2) Which vehicle requirements would give the most military advantage if exceeded?

Mission Profiles

3) What are typical mission profiles for stealth mode?
   a) terrain
   b) duration of stops, duration of moves
   c) speed
   d) auxiliary power required
   e) longest time between battery charges

4) What are typical mission profiles for dash mode?
   a) terrain
   b) duration
   c) speed
   d) auxiliary power required

5) What situations drive the turning radius requirement? What is the impact of a smaller or larger turning radius on the ability to conduct operations?

6) What situations drive the turning (dynamic) requirement? What is the impact of a smaller or larger turning (dynamic) capability on the ability to conduct operations?

7) When is central tire inflation of value? What types of terrain? What transition times are appropriate to go from one inflation level to another?

8) What is the required crew size for typical RST-V missions? Unique missions?

Mobility

9) What are the most important mobility capabilities? For each mission type?

10) What kinds of terrains are presently considered un-crossable? Which of these terrains would give the most benefit if crossable?

11) Is there much value in being able to exceed longitudinal slope, side slope, or vertical step requirements? At what speed?

12) How important is fording speed?

13) What kinds of mobility characteristics would be most valuable, if "blue sky", advanced concepts are developed?

Survivability

14) What are the most important survivability capabilities? For each mission type?

15) How much does the user want to depend on having armor, rather than on other means to avoid being attacked or mined, such as threat detection, acquisition avoidance, or hit avoidance? How much armor is appropriate? For what types of threats? What trades are appropriate between types and amounts of armor vs other technologies?

16) What types of mines can we detect so we can avoid them? Are mine detectors effective? Airborne mine sensors? Can mine detectors / mine triggering devices be trusted to the extent of not armoring the underside of the vehicle?

17) What is desired location for sensors? Are air borne or elevated sensors appropriate? What types? Would the soldier elevate these sensors to see, or keep them low to avoid detection?

18) What are dominant characteristics by which vehicles are detectable?
   a) acoustic
   b) visual / UV
   c) infra-red (SWIR, MWIR, LWIR)
   d) radar / millimeter wave
   e) magnetic
   f) bio-chemical
   g) weight / tracks

19) What kinds of stealth characteristics would be most valuable, if "blue sky", advanced concepts are developed?

On-Vehicle Equipment (OVE)

20) What OVE selections are appropriate for each type of mission?
   a) communications gear
   b) weapons & ammunition
   c) special purpose surveillance and target acquisition gear
   d) position location and navigation gear
   e) bolt-on armor

21) What OVE must be accessible instantly (eg, under attack)?

22) Would there be any benefit to a remote-controlled, stabilized gun mount?

23) What type of weapons are essential? Which are desireable? If fired from the vehicle, what should the traversing capabilities be?

Soldier Preferences

24) In general, do you prefer automatic controls or manual controls, i.e., transmission, differential locks, CTI, sensors, etc.?

25) Would users prefer an open cab or an environmentally controlled, closed cab?

26) What is minimum acceptable visibility?

27) What type of information would the driver like to have displayed?

28) What is the user's seating preference?

29) How important is a cold weather package, i.e., defroster / heater?

30) What are your biggest concerns with existing light weight military vehicles? How about the HMMWV?

APPENDIX D

Diesel Engine Survey

DIESEL ENGINES (PARTIAL LISTING SORTED BY BRITISH HORSEPOWER)

		POWER				TORQUE			RPM-PEAK	WEIGHT		DISPLACE		LENGTH		WIDTH		HEIGHT		FUEL	# OF	ASPIR
MANUFACTURER	MODEL	BHP	KW	MHP	@ RPM	LBFT	NM	KG	TORQUE	KG	LB	CUIN	L	MM	IN	MM	IN	MM	IN	SYSTEM	CYLs	-ATION
RPI	LOCR 814 SD	40	30	41	3600					50	110	49	0.81	508	20.0	363	14.3	381	15.0	D	2	N
VW	1.9 ADG	58	43	58	4000	89	121	12.34	2200	130	286	116	1.90	530	20.9	625	24.6	637	25.1	I	4	N
MAZDA	R2-22	60	45	61	4250	98	133	13.57	2000	158	348	134	2.20	668	26.3	531	20.9	655	25.8	I	4	
MAZDA	XA-25	63	47	64	3000	118	160	16.32	2200	249	548	153	2.50	754	29.7	533	21.0	683	26.9	I	4	
MAZDA	SL-35	72	54	73	3400	164	222	22.64	1800	260	572	207	3.40	738	29.1	598	23.6	715	28.2	D	4	T
VW	1.9 ADE	75	56	76	4000	113	153	15.61	1700	135	297	116	1.90	531	20.9	677	26.7	637	25.1	I	4	T
MAZDA	HA-30	76	57	78	3000	145	197	20.09	2000	251	552	177	3.00	754	29.7	533	21.0	684	26.9	I	4	T
VW	1.9 AFD	90	67	91	4000	149	202	20.6	1900	135	297	116	1.90	546	21.5	711	28.0	638	25.1	D	4	TDI
PEUGEOT	XUD9TE	90	67	91	4000	145	197	20.09	2250	140	308	116	1.90	566	22.3	650	25.6	655	25.8	I	4	TI
MITSUBSH	4D68	93	69	94	4500	145	197	20.09	2500	167	367	122	2.00	660	26.0	565	22.3	560	22.1	I	4	TI
FORD/EUR	FSD425T	98	73	99	4000	167	226	23.05	2100	236	519	153	2.50							I	4	T
FORD EUR	FSD425T	98	73	99	4000	167	226	23.05	2100	236	520	153	2.50	667	26.3	690	27.2	777	30.6	I	4	N
NISSAN	BD30	99	74	101	3800	159	216	22.03	2000	243	535	177	2.90	710	28.0	660	26.0	715	28.2	I	4	?
MAZDA	TF-40	101	75	102	3250	188	255	26.01	2000	327	719	244	4.00	785	30.9	765	30.1	716	28.2	D	4	T
MITSUBSH	4D56	105	78	106	4200	177	240	24.48	2000	200	440	153	2.50	691	27.2	600	23.6	715	28.2	I	4	TI
PEUGEOT	XUD11ATE	105	78	106	4300	177	240	24.48	2000	171	376	128	2.10	592	23.3	623	24.5	675	26.6	I	4	TI
PERKINS	PHASER 110T	110	82	112	2600	281	381	38.86		279	614	243	4.00							D	4	T
ROVER	300 TDI	111	83	113	4000																4	
VM	425 CDIE	113	84	114	4000	203	275	28.05	1800	220	484	153	2.50	694	27.3	584	23.0	595	23.4	D	4	TI
FORD	LSG 423	113	84	114	4800	135	183	18.67	2400	178	393	140	2.30	640	25.2	671	26.4	622	24.5	6	4	N
IVECO	8140.47	114	85	116	3800	181	245	24.99	2000	235	517	153	2.50							I	4	TA
FORD EUR	DOC420I	114	85	116	5500	123	167	17.03	2500	130	287	122	2.00	610	24.0	589	23.2	721	28.4	I	4	N
STEYR	M 14 TCA	115	86	117	4300	188	255	26.01	1800	180	395	128	2.10							D	4	TD
IVECO	8144.97	115	86	117	4100	185	251	25.6	2400	230	506	153	2.50							I	4	TA
VM	425 CLIR	118	88	120	4200	193	262	26.72	2200	208	458	153	2.50	681	26.8	615	24.2	671	26.4	I	4	T
AUDI	5 CYL TDI	118	88	120	4250	196	266	27.13	2250	200	440	153	2.50	673	26.5	632	24.9	780	30.7	D	5	TI
VM	425 CLIE	123	92	125	4200	217	294	29.99	2150	208	458	153	2.50	680	26.8	615	24.2	669	26.4	I	4	TI
FORD EUR	CSG649	125	93	126	3600	237	322	32.84	2000	215	474	299	4.90	896	35.3	622	24.5	735	28.9	I	6	N
PEUGEOT	DK5ATE	127	95	129	4300	210	285	29.07	2000	209	460	153	2.50	787	31.0	783	30.9	685	27.0	D	4	TI
LANDROVE	LR 3.6P	134	100	136	5000																8	
FORD EUR	DOC420I 16V	134	100	136	6300	129	175	17.85	4200	133	293	122	2.00	658	25.9	633	24.9	671	26.4	I	4	N
PERKINS	PHASER 135TI	135	101	137	2600	328	445	45.39		410	902	243	4.00							D	4	TI
AUDI	5 CYL 140HP	141	105	143	4000	214	290	29.58	2000	210	440	153	2.50	673	26.5	632	24.9	780	30.7	D	5	TI
STEYR	M 15 TCA	142	106	144	4300	236	320	32.64	1800	209	459	165	2.70							D	5	TD
FORD	CSG 649	145	108	147	3400	265	359	36.62	2000	254	560	300	4.90	962	37.9	622	24.5	735	28.9	I	6	N
VM	531 CLIE	148	110	150	4200	272	369	37.64	2000	250	550	189	3.10	686	27.0	615	24.2	782	30.8	I	5	TI
VM	531 CDIE	150	112	152	4000	272	369	37.64	1800	253	557	189	3.10	686	27.0	615	24.2	782	30.8	D	5	TI
GMVO	6.5 V8 D NA	160	119	162	3400	300	407	41.51	1700	292	644	395	6.50	752	29.6	897	35.3	770	30.3	I	8	N
STEYR	M 16 TCA	172	128	174	4300	280	380	38.76	1800	225	495	195	3.20							D	6	TI
IVECO	8060.25	174	130	177	2700	413	560	57.12	1400	460	1012	360	5.90							D	6	TI
DD	SERIES 40	176	131	178	2600	430	583	59.47	1800	568	1250	409	6.70	1143	45.0	711	28.0	1016	40.0	D	8	T
VM	638	177	132	180	4200	325	441	44.98	2000	290	639	229	3.75	899	35.4	615	24.2	691	27.2	D	6	TI
PERKINS	PHASER 180TI	178	133	181	2600	475	644	65.69		419	922	365	6.00							D	6	TI
VM	D 642	178	133	181	3200	325	441	44.98	1800	290	638	254	4.16	953	37.5	572	22.5	714	28.1	D	6	TI
GMVO	6.5L V8 THPD	190	142	193	3400	385	522	53.24	1700	312	687	395	6.50	752	29.6	897	35.3	770	30.3	I	8	T
FORD	CSG 850	194	145	197	4000	199	270	27.54	3000	254	561	302	5.00	769	30.3	622	24.5	717	28.2	I	8	N
STEYR	M 16TCAHD	197	147	200	4000	295	400	40.8	2300	225	495	195	3.20							D	6	TI

APPENDIX E

General Engine Survey

Diesel Engines

Power Range (BHP)	Mfg	Model Number	Weight (lb)	BHP x rpm	BHP/lb	T (ft-lb) x rpm	Comments
50 - 100	VW	1.9 AFD	297	90 x 4000	0.30	149 x 1900	116 cu in, 1.9L, 21.5"L x 28"W x 25.1"H, 4 cyl Turbo Direct Injection
50 - 100	Peugeot	XUD9TE	308	90 x 4000	0.29	145 x 2250	116 cu in, 1.9L, 22.3"L x 25.6"W x 25.8"H, 4 cyl Turbo Induction
50 - 100	Mitsubishi	4D68	367	93 x 4500	0.25	145 x 2500	122 cu in, 2.0L, 26.0"L x 22.3"W x 22.1"H, 4 cyl Turbo Induction
50 - 100	VW	1.9 ADE	297	75 x 4000	0.25	113 x 1700	116u in, 1.9 20.9"L x 26.7"W x 25.1"H, 4 cyl Turbo
101 - 125	Ford Eur	DOC420I	287	114 x 5500	0.40	123 x 2500	122 cu in, 2.0L, 24.0"L x 23.2"W x 28.4"H, 4 cyl Naturally Aspirated
101 - 125	Ford	LSG 423	393	113 x 4800	0.29	135 x 2400	140 cu in, 2.3L, 25.2"L x 26.4"W x 24.5"H, 4 cyl Naturally Aspirated
101 - 125	Steyr	M14 TCA	395	115 x 4300	0.29	188 x 1800	128 cu in, 2.1L, 4 cyl Turbo Direct Injection
101 - 125	Peugeot	XUD11ATE	376	105 x 4300	0.28	177 x 2000	128 cu in, 2.1L, 23.3"L x 24.5"W x 26.6"H, 4 cyl Turbo Induction
126 - 150	Ford Eur	DOC420I	293	134 x 6300	0.46	129 x 4200	16V, 122 cu in, 2.0L, 25.9"L x 24.9"W x 26.4"H, 4 cyl Naturally Aspirated
126 - 150	Audi		440	141 x 4000	0.32	214 x 2000	153 cu in, 2.5L, 26.5"L x 24.9"W x 30.7"H, 5 cyl Turbo Induction
126 - 150	Steyr	M15TCA	459	142 x 4300	0.31	236 x 1800	165 cu in, 2.7L, 5 cyl Turbo

Diesel Engines							
Power Range (BHP)	**Mfg**	**Model Number**	**Weight (lb)**	**BHP x rpm**	**BHP/lb**	**T (ft-lb) x rpm**	**Comments**
126-150	Peugeot	DK5ATE	460	127 x 4300	0.28	210 x 2000	153 cu in, 2.5L, 31.0"L x 30.9"W x 27.0"H, 4 cyl Turbo Induction
151 - 175	Steyr	M16TCA	495	172 x 4300	0.35	280 x 1800	195 cu in, 3.2L, 6 cyl Turbo Induction
151 - 175	GM	6.5L	644	165 x 3400	0.26	300 x 1700	395 cu in, 6.5L, 30.5"L x 26.2"W x 28.4"H, 8 cyl Naturally Aspirated
176 - 200	RPI	2013R	340	200 x 6000	0.59	175 x 6000	81 cu in, 1.33L, 24.1"L x 29.3"W x 17.7"H, 2 cyl Turbo Induction
176 - 200	Steyr	M16TCAHD	225	197 x 4000	0.40	295 x 2300	195 cu in, 3.2L, 6 cyl Turbo Induction
176 - 200	Ford	CSG850	561	194 x 4000	0.35	199 x 3000	302 cu in, 5.0L, 30.3"L x 24.5"W x 28.2"H, 8 cyl Naturally Aspirated
201 - 250	Ford Eur	CSG850	536	235 x 4800	0.44	278 x 4000	305 cu in, 5.0L, 29.4"L x 26.1"W x 28.7"H, 8 cyl Turbo
201 - 250	GM	6.5L-TD	687	250 x 3600	0.36	400 x 2400	395 cu in, 6.5L, 30.5"L x 26.2"W x 28.4"H, 8 cyl
201 - 250	Ford	NSD873T	860	211 x 3000	0.25	425 x 2000	445 cu in, 7.5L, 33.1"L x 27.8"W x 34.6"H, 8 cyl Turbo
201 - 250	Cummins	B5.9	942	230 x 2200	0.24	605 x 1400	359 cu in, 5.9L, 40"L x 35.5"H x 32.4"W, 6 cyl
250 +	Deere	6081H	1710	255 x 2200	0.15		496 cu in, 8,1L, 47.6"L x 28.6"W x 40.2"H, 6 cyl
250 +	Deere	1058R	910	375 x ?	0.41		350 cu in, 5.8L, Rotary Diesel

Notes:

1. Only diesel engines, from reputable suppliers, were considered since this is the primary choice of most military services & contractors.
2. There are many other engines available. The engines chosen in the table were the top 3 or 4 candidates in each power range in terms of their BHP/lb rating.
3. The highest power-to-weight ratios are the RPI 2013R and the Deere 1058R which are rotary diesel engines. Neither has earned any production market share to date, perhaps due to their relatively low torque. These engines are smaller and lighter because they do not have to convert reciprocal motion into rotary motion like conventional engines do. They are also omnivorous, or, intolerant to fuel quality. In fact, they can run on diesel, gasoline or even jet fuel. Another important advantage to military applications are their stealth advantages. Rotary diesels have lower heat rejection rates (lower IR signature) and the dominant source of noise is the exhaust which can be treated with silencers.
4. The Steyr engines look good but lack logistic support as they have not been made in production quantities to date. Rod Millen uses a 6 cylinder Steyr engine in the HTTMP and has not been impressed by Steyr's support.
5. Europeans are estimating a 50% increase in future power densities as a result of using multiple valves per cylinder.

Gasoline Engines

Power Range (BHP)	Mfg	Model Number	Weight (lb)	BHP x rpm	BHP/lb	T (ft-lb) x rpm	Comments
50 - 100	Mitsubishi	4G63	315	90 x 5000	0.28	101 x 1800	2L, 4 cyl in line
50 - 100	Peugot	TU5JP	221	100 x 5600	0.22	100 x 3000	1.6l, 4 cyl in line, horizontal, liq cooled
101 - 125	Ford	LSG423	319	119 x 5400	0.37	127 x 2800	2.2L, 4 cyl in line, horizontal, liq cooled
101 - 125	GM	2.2L (MPFI)	280	110 x 5200	0.39	123 x 2700	2.2L, 4 cyl in line, horizontal, liq cooled
101 - 125	Peugot	XU92C	283	107 x 6000	0.38	118 x 3000	1.9L, 4 cyl in line, horizontal, liq cooled
126 - 150	GM	3.0L (TBI)	363	148 x 4800	0.41	185 x 3600	2.2L, 4 cyl in line, horizontal, liq cooled
126 - 150	Mitsubishi	6A11	313	133 x 6000	0.42	108 x 3500	1.6L, V6
126 - 150	Peugot	XU10J2TE	298	139 x 4400	0.58	168 x 2200	2.0L, 4 cyl in line, horizontal, liq cooled
151 - 175	Mitsubishi	6G72	375	153 x 5000	0.41	163 x 2500	2.5L. V6
176 - 200	Peugot	XU10J4TE	364	192 x 5000	0.53	214 x 2600	2.0L, 4 cyl in line, horizontal, liq cooled
176 - 200	GM	4.3L (2-BBL)	388	184 x 4400	0.47	230 x 2400	4.3L, V6, horizontal, liq cooled
201 - 250	Ford	CSG649	473	213 x 4200	0.45	245 x 2000	4.9L 6 cyl in line, horizontal, liq cooled
201 - 250	GM	4.3L (TBI)	388	211 x 4600	0.54	265 x 2800	4.3L, V6 horizontal, liq cooled
250 +	Ford	LSG875	713	339 x 4600	0.47	373 x 1700	7.6L V8, horizontal, liq cooled
250 +	GM	5.7L HO (TBI)	473	280 x 4400	0.59	330 x 3200	5.7L, V8, horizontal, liq cooled

Notes:

1. Gasoline engines are typically lighter than equivalent diesel engines due to the lower operating pressures.

APPENDIX F

Propulsion System Calculations

<u>**Max Speed**</u> -- Requirement = 75 mph (level ground)

- **Rolling Resistance on Pavement:**

  Frr = 0.03 * 6500 lb = 195 lb

- **Air Resistance (Far = 0.26 Cd $A_f (V/10)^2$)**

  Far = 0.26 * 0.75 * 22 * $(75/10)^2$ = 241.3 lb

- **Required Engine Power:**

  (Σ F) (V) / 375

  (195 + 241.3) * 75 / (375 * 80% eff) = 109 hp (81 kW)

- **Engine Speed:**

  (611.5 rev/mi) * 75 mi/hr * 4.56 * 1 * 0.75 * 1 / 60 min/hr = 2613 rpm

<u>**Start on 60% Slope**</u>

- **Rolling Resistance on medium soil:**

  Frr = fw = (0.1) * (6500 lb) = 650 lb

- **Grade Resistance:**

  Fg = wg = 60% * (6500 lb) = 3900 lb

- **Total Force at Wheels:**

  (Frr) + (Fg) = 650 lb + 3900 lb = 4550 lb

- **Torque on Axles:**

  (4550 lb) * 1.31 ft = 5960 ft-lb

- **Max Engine Torque Required:**

  (5960 ft-lb) / (4.56 * 1 * 2.48 * 1.9) = 277 ft-lb

<u>**Climb 5% Grade at 40 mph**</u>

- **Rolling Resistance on medium soil:**

  Frr = fw = (0.1) * (6500 lb) = 650 lb

- **Air Resistance:**

  Far = 0.26 * 0.75 * 22 * $(40/10)^2$ = 68.6 lb

- **Grade Resistance:**

  Fg = wg = 5% * (6500 lb) = 325 lb

- **Required Engine Power:**

  (650 + 68.6+ 325) * 40 / (375 * 80% eff) = 139 hp (104 kW)

Tow Self & Equal up 40% Slope

- **Rolling Resistance on medium soil:**

  Frr = fw + fw = 2*[(0.1) * (6500 lb)] = 1300 lb

- **Air Resistance Neglected**
- **Grade Resistance:**

  Fg = wg = 40% * (13000 lb) = 5200 lb

- **Using 139 hp as calculated above:**

  HP = (Σ F) (V) / 375

  Solving for V:

  V = (139) * (375) * 80% / (1300 + 5200) = 6.42 mph

Acceleration (ROM estimate only)

- **Requirement: 0 to 30 mph in 6 seconds**

  $V_f = V_i + at$

  a = 44 fps / 6 sec = 7.33 ft/sec^2

  F = ma = w/g * a = (6500 lb) * 7.33 ft/sec^2 / 32.2 ft/sec^2 = 1480 lb

  Rolling Resistance on pavement:

  Frr = fw = 0.03 * 6500 lb = 195 lb

  HP = (1480 + 195) * (30) / (375 * 80%) = 168 hp (125 kW)

- **Requirement: 0 to 60 in 15 seconds**

  Determine acceleration from 30 to 60 mph in 9 seconds

  $V_f = V_i + at$

  a = (88 fps - 44 fps) / 9 sec = 4.89 ft/sec^2

  Far = 0.26 * 0.75 * 22 * (60/10)^2 = 154.4 lb

  F = ma = w/g * a = (6500 lb) * 4.89 ft/sec^2 / 32.2 ft/sec^2 = 988 lb

  Vrms = SQRT [(60^2 + 30^2)/2] = 47.4 mph

  HP = (154.4 + 195 + 988) * (47.4) / (375 * 80%) = 211 hp (157 kW)

  HP_{0-60} = SQRT [(168^2 + 211^2)/2] = 191 hp (142 kW)

APPENDIX G

Technology Tree for Light Strike/Reconnaissance Vehicles

Technology Tree for Light Strike / Reconnaissance Vehicles (Top Level)

Mobility

A) propulsion
   1) engine
   2) battery
   3) transmission
   4) differential
   5) hybrid drive
   6) motor/wheel

B) suspension
   1) springs
   2) shocks
   3) active control

C) vehicle support
   1) fuel
   2) lubricants
   3) coolant
   4) OVE items
   5) occupant protection

Survivability

A) acquisition avoidance ** (acoustic, radar, thermal, visual, magnetic)
   1) signature mgmt (paints, materials, covers, elect control)
   2) decoys (passive, active, remote, local)
   3) sensor jamming (wide or narrow bandwidth)

B) hit avoidance
   1) overload
   2) spoofing
   3) anti-ballistic weapons
   4) high energy defense

C) penetration avoidance **
   1) applicae armor
   2) reactive armor
   3) ceramics
   4) composites
   5) spall liner

D) kill avoidance
   1) fire prevention & suppression
   2) crew partitioning
   3) NBC alarm/protection

E) threat detection ** (wide area sensors, mine detection)
   1) IR
   2) visual / UV
   3) radar / mm wave
   4) magnetic
   5) acoustic
   6) external data

Firepower

A) weapons
   1) TOW launchers
   2) grenade launchers
   3) machine guns
   4) small caliber
   5) high energy

B) ammo storage
   1) TOW missiles
   2) grenades
   3) machine gun ammo
   4) small caliber ammo
   5) mines

C) target acquisition ** (accurate tracking sensors)
   1) IR
   2) visual / UV
   3) radar / mm wave
   4) magnetic
   5) acoustic
   6) external data

C4I

A) external communication
   1) vehicle mounted radio
   2) portable radios
   3) secure voice radios
   4) antennas
   5) satellite links

B) internal communication
   1) radios in helmets

C) position location
   1) GPS
   2) PLRS
   3) inertial reference
   4) attitude reference

D) computations
   1) ruggedized processor
   2) rad-hard capability

** Initial Focus

APPENDIX H

Survivability Survey Results

Assessment of Technologies

Assessment Parameters

- Ef = Effectiveness in percent success
- $$ = Production Cost in dollars per vehicle
- Wt = Weight in pounds per vehicle
- Yr = Year of Technology Readiness

Quality of Assessment

- 1 = engineering judgement (generally within factor of 2 of correct assessment)
- 2 = based on application of technology to an existing product
- 3 = calculated using quantitative evaluation of technology as applied to our system
- 4 = demonstrated by actual application to our system testbed

Assessment Example

(Ef1: 25) ($$1: 350) (Wt1: 45) (Yr1: 2001) says that

- Effectiveness rating (using engineering judgement) causes success in 25 percent of situations (for example, for acoustic signature reduction technologies, if vehicle would have been detected acoustically in 100 scenarios, the technology being assessed reduces the detection by 25 percent to 75 scenarios)
- Production Cost (using engineering judgement) is 350 dollars for one vehicle
- Weight (using engineering judgement) is 45 pounds for one vehicle
- Year of technology availability (for initiating design) (using engineering judgement) is 2001

Technology Tree for Light Strike / Reconnaissance Vehicles (Second Level)
Survivability Item A1 -- Acquisition Avoidance -- Signature Management

Signature	Selection of Materials	Control Techniques	System Design Approach
Acoustic	• basic paints have very little sound deadening capability; paints which trap air bubbles have minor acoustical benefits (Ef1: <1) ($$1: 50) (Wt1: 10) (Yr1: 1996) • materials constructed with dead air spaces have sound-deadening capabilities; a rough surface breaks up acoustic reflections, as well as attenuating radiated noise (Ef1: 1) ($$1: 500) (Wt1: 50) (Yr1: 1996) • material sandwiches with loose (or indirect) physical coupling between the outer surfaces are very good at attenuating acoustical transmissions; the center of the sandwich should be composed of lots of small dead air spaces, such as foam (Ef1: 5) ($$1: 500) (Wt1: 200) (Yr1: 1996) • covers constructed as material sandwiches provide good acoustical attenuation (Ef1: 5) ($$1: 500) (Wt1: 100) (Yr1: 1996)	• electronic noise cancellation can provide excellent attenuation of regular low frequency noise generated at the vehicle, especially if the noise cancellation signal is nearly co-located with the source; this applies to noise such as the hum produced by rotating machinery, but does not help well with white noise. (Ef1: 10) ($$1: 1K) (Wt1: 50) (Yr1: 1996)	• stealth movement using electric drive only will significantly reduce the acoustical signature does not help well with white noise. (Ef1: 80) ($$1: 20K) (Wt1: TBD) (Yr1: 1998) • use of low road noise tires will improve remaining signature (Ef1: 10) ($$1: 400) (Wt1: 50) (Yr1: 1998)
Ultra-violet / Visual	• ultra-violet and visual signatures are mostly dominated by the surface characteristics of the materials; paints or other surface characteristics can match the ultra-violet or visual characteristics of the background; (Ef1: 20) ($$1: 500) (Wt1: 10) (Yr1: 1996) • changeable background characteristics require that the surface coating itself be responsive to the environment; this technology is likely to be in the formative stages at this time, and probably be useable in the 5-8 year time frame. Such technology is probably classified. (Ef1: 80) ($$1: 25K) (Wt1: 100) (Yr1: 2002)	• see note in "materials" column. technology to change surface characteristics is likely to be based on a combination of chemical and electronic technologies	•

115

Signature	Selection of Materials	Control Techniques	System Design Approach
Infra-red / Thermal	• paints can be designed to provide some degree of thermal insulation, thereby reducing the MWIR / LWIR (thermal) signature (Ef1: 10) ($$1: 400) (Wt1: 50) (Yr1: 1996) • paints can be designed to radiate poorly in the SWIR ranges (Ef1: 20) ($$1: 400) (Wt1: 50) (Yr1: 1996) • responsive surface material -- see note under ultra-violet / visual materials (Ef1: 20) ($$1: 20K) (Wt1: 500) (Yr1: 1996) • materials which are good insulators provide reasonable thermal signature attenuation (Ef1: 50) ($$1: 2K) (Wt1: 300) (Yr1: 1996) • low signature covers can be designed using the other techniques for materials	• electronic transfer of heat to the center of the vehicle will reduce the thermal signature	•
Radar / Millimeter Wave	• paints which are properly designed have low radar reflectivity, by incorporating materials which do not interact with the electromagnetic environment • the physical configuration of materials used has a strong influence on radar (& mm wave reflectivity) • selected materials provide substantially reduced EM interactions, yielding reduced radar reflectivity • materials which absorb radar energy but do not re-radiate the energy would be optimum for use (details are not presently known by our team) • note also that materials which are transparent to radar let the radar signal propagate to the inner materials • covers need to be designed with radar absorbing materials	• electronic control techniques can most likely be used to enhance the radar absorption of the materials used. Specific materials and control techniques are not presently known by our team.	•
Magnetic	materials which are non-magnetic can be used to minimize the magnetic signature	• electronic control techniques should be able to provide magnetic shielding to effectively eliminate the external magnetic signature (e.g., below the vehicle)	•
Bio-Chemical	• paints and materials which have cured, and are no longer outgassing should not leave a significant bio-chemical signature • use of very clean burning fuels (such as propane) can substantially reduce the bio-chemical signature • bio-chemical signature scrubbers such as activated charcoal can be used to clean up problem areas	electronic (high voltage) scrubbers can be used to help reduce the bio-chemical signature	•
Weight	wide tires can distribute the weight and leave less of an imprint	N/A	

Technology Tree for Light Strike / Reconnaissance Vehicles (Second Level)
Survivability Items A2 and A3 -- Acquisition Avoidance -- Decoys & Sensor Jamming

Observable Signature	Technology Approach for Generating Decoys & Sensor Jamming	
	Decoys	Jamming

Acoustic	• noise makers are small, lightweight, disposable
	• deployment techniques
	  • drop off
	  • launch/lob from vehicle
	  • tow behind vehicle on tether
		• directed energy (acoustic or other) at the offending sensor is more appropriate than wide bandwidth jamming; operationally unattractive

Ultra-violet / Visual	• stationary: quick inflation balloons, shaped like vehicles, men, ... • mobile: quick inflation balloons, on wheels, small drive motor, controlled similarly to model planes	• directed energy at the offending sensor is more appropriate than wide bandwidth jamming; operationally unattractive
Infra-red / Thermal	• same as for UV/visual	• directed energy at the offending sensor is more appropriate than wide bandwidth jamming; operationally unattractive
Radar / Millimeter Wave	• objects with higher reflectivity than the vehicle can be deployed (equivalent to corner cube for optical reflections)	• straightforward technology, but operationally unattractive
Magnetic	Not Applicable	Not Applicable
Weight	Not Applicable	Not Applicable

Technology Tree for Light Strike / Reconnaissance Vehicles (Second Level)
Survivability Item E -- Threat Detection

Observable Signature	Technology Approach for Threat Detection		
	Omni-direction Sensors	**Scanning Sensors**	**Mine detection**
Acoustic	• microphones, along with pattern recognition software can identify known signals even in substantial background noise	• scanning sensors have little benefit, unless the direction of the threat is known; then directional capability is valuable to enhance the signal relative to noise prior to processing	• mines which are triggered by vibration could be triggered by acoustics
Ultra-violet / Visual	• muzzle flash detection (large weapon) can be performed by an omni-directional sensor • detection of threats other than muzzle flashes requires image detection and processing, and a sensor with a narrower field of view than an omni-directional sensor	• tremendous detection capability is available and requires significant image processing; detectability depends on processing capability, stealth techniques used by threat, location of sensor, threat	• well designed mines can be hidden from UV and visible sensors
Infra-red / Thermal	• detection requires image detection and processing, and a sensor with a narrower field of view than an omni-directional sensor	• tremendous detection capability is available and requires significant image processing; detectability depends on processing capability, stealth techniques used by threat, location of sensor, threat; use of MWIR can be most effective, at higher cost	• well designed mines can be hidden from IR sensors
Radar / Millimeter Wave	• omni-directional sensors can detect radar being transmitted by a threat	• scanning radar can identify threrats, but only at the expense of radiating energy, and thereby becoming easily detectable • scanning bi-static radar, with the transmitter located remotely from the vehicle is not susceptible to the detectability problem	• radar can theoretically detect metal objects underground • •
Magnetic	•	•	•
Weight	•	•	•
External Data	•	•	•

Index	Tech. Category	Det./ Acq.	Vehicle Types	Company
2	Acoustic	Det	All * Handheld	Jaycor
53	Bio-Chemical	Det	All	Argonne National Laboratory
54	Bio-Chemical	Det	All	Argonne National Laboratory
1	Bio-Chemical	Det	All	Jaycor
60	Bio-Chemical	Det	All	OCETA Enviro.Tech. - Barringer Res. Ltd
49	Bio-Chemical	Det	All	U.S. Army Edgewood RDEC
3	Bio-Chemical	Det	All * Handheld	Rocketdyne, et al.
50	Bio-Chemical	Det	All * Handheld	U.S. Army Edgewood RDEC, Aberdeen - Skunkworks Projects
52	Bio-Chemical	Det	All * Handheld	U.S. Army Edgewood RDEC, Graesby Dynamics, Ltd.
51	Bio-Chemical	Det	All * Handheld	U.S. Army Edgewood RDEC, Graesby/FemtoScan, University of Utah - SBIR Program
12	Comm. Intercept	Det	All	P.O.C. Mr. John Holzman, DSN 229-6816, COMM 703-349-6816
69	Infrared	Acq	All	
73	Infrared	Acq	All	
79	Infrared	Acq	All	
40	Infrared	Acq	All	MICOM RDEC
39	Infrared	Acq	All * Weap. Mount	Insight Technology
62	Infrared	Acq	All * Weap. Mount	Rapid Acquisition Targeting Systems
48	Infrared	Acq	All * Weap. Mount	Santa Barbara Research Center
67	Infrared	Det	All	Amber (Raytheon)
65	Infrared	Det	All	Amber (Raytheon)
66	Infrared	Det	All	Amber (Raytheon)
64	Infrared	Det	All	Amber (Raytheon)
34	Infrared	Det	All	Inframetrics
81	Infrared	Det	All	Inframetrics
24	Infrared	Det	All	Texas Instruments
82	Infrared	Det & Acq	All	Inframetrics
35	Infrared	Det & Acq	All	Inframetrics
36	Infrared	Det & Acq	All * Handheld	Litton
43	Infrared	Det & Acq	All * Weap. Mount	Hughes
31	Infrared	Det & Acq	All * Weap. Mount	Hughes
42	Infrared	Det & Acq	Med, ?LW, SLW?	Hughes
37	Infrared	Det & Acq	Med, ?LW, SLW?	Texas Instruments (P) & Hughes (Sub)
71	Laser	Acq	All	

119

Index	Product Name	Product ID	Weight
2	Ultrasonic Imaging Technology		Hand held
53	Associated-particle, sealed-tube neutron generator	APSTNG	
54	Handheld Portable X-ray Fluoresence Spectrum Analyzer		
1	Spectrophone		Man-portable
60	IONSCAN IMS Detection System	IONSCAN	35lbs for Detector Module,
49	Joint Services Lightweight Standoff Chemical Agent Detector	LSCAD (JSLSCAD)	Prototype 22 lbs
3	Ecoscan		Man portable (picture at UR
50	Lightweight Chemical Detector (LCD) w/ Data Archival	LCD	2.6 lbs
52	Miniature Ion Mobility Spectrometer	Mini-IMS	1.6 lb
51	Environmental Vapor Monitor (EVM II)	EVM II	Hand held
12	Lightweight Man-Transportable Radio Direction Finder System LMRDFS	AN/PRD-12	Two Man Portable
69	AIM-1	AIM/MLR, AIM/EXL, AIM-1/D, AIM-1/DLR, AIM-1/MLR, AIM-1/EXL	Weapon/Turret Mounted
73	Ground Commanders Pointers	GCP-1, GCP-1A NSN: 5855-01-420-0849	4.5 oz
79	Nite Eye		1.1 kg
40	Small Diameter Seeker (Block II Stinger) and TACAWS Infrared Seeker (		
39	Infrared Aiming Light	AN/PAQ-4. AN/PAQ-4A. AN/PAQ-4B, AN/PAQ-4C, AN/PEQ-1 S	2.7 oz (76.68 g) w/o batteri
62	RATS 840 Infra-Red (IR)	RATS 840 IR	
48	Staring and Scanning Focal Plane Arrays	SADAII, SADAIIIB, et al.	
67	Argus Sentry		Enclosure w/housing = 60 l
65	Aurora (Radiance Aurora)		10 lbs
66	Galileo (MWIR Camera System)		<=9lbs
64	Sentinel		4.5 lbs w/battery, 3.8 lbs w/
34	MilCAM		4lbs (1.818 kg)
81	Thermacam		2.6 kg total, 1.7 kg camera
24	Driver's Vision Enhancer (DVE)	AN/VAS-5 (D1000)	<17 lbs
82	Infracam		2.93 lbs total
35	Long Range Infrared System	LORIS	35 lbs (15.9 kg)
36	Mini Eyesafe Laser Infrared Observation SET (MELIOS	AN/PVS-6	4 lbs, 6.5 lbs w/tripod, 13 lb
43	Multipurpose Thermal Sight	AN/PAS-19	Man Portable
31	Thermal Weapon Sight	AN/PAS-13	Man Portable
42	Hughes Infrared Equipment (HIRE), GMHE Integrated TOW Sight	HIRE - ITS	Light weight - modular
37	Horizontal Technology Integration Second Generation FLIR	HTISGF	
71	Ground/Vehicle Laser Locator Designator	AN/TVQ-2 (G/VLLD)	Man Portable

Index	Unit Price	Space Reqs	Power Reqs	Availability
2		Hand Held		Future
53	inexpensive	relatively small		Prototype - needs ruggedization and additional
54		Hand Held		Current
1				Future- Chemical Fingerprints (baselines) nee
60		14" x 12.5" x 12.5" Detector, 8.5" x 12.5" x 12.5" Pump	110/220 VAC, DC option available	Current
49		0.3 cu ft + turret scanner 10 cu inches, + a 17" x 13" oval	28 VDC at 2 amps	Prototype
3	1/10th of current	Hand Held		Current -1995
50	$100's/unit (+dat	Prototype: 8" x 3.5" x 3", Next Generation: 7" x 2" x 1.5"	<1 watt	Prototype available
52	relatively low	.02 cu ft	Battery or External Power	Current
51		Hand Portable	24VDC - Battery or Extermal Power supply	Current
12				1996
69		Weapon/Turret Mounted		Currently Fielded
73		Used with Night Vision devices	2 - AA Batteries	Currently Fielded
79			2 AA Batteries	Currently Fielded
40		2.75" diameter, 5.85" diameter		
39	$402	5.5"L x 2.5"H x 1.2"W sight, 8" x 12" x 10" Transit Case	1 BA-5567 or 2 AA batteries (BA-3058)	Currently fielded
62		.48"W x .40"H x .50"L	6VDC, PX28L Battery Type	Current
48		Weapon Integrated		Current
67		Camera = 4.4"W x 10.3"D x 7.2" H, Rain Shield 6" x 10"	120V AC/60 HZ or 230V AC/ 50 HZ, 350 Watts max,	Current
65		5.1"W x 9"D x 5.4"H	19V to 36V DC, 55 watts	Current
66		4.2"W x 6.75"D x 5.7"H		Current
64		4.5"W x 3.5" H x 5" L	6VDC typ, 6.8VDC max. Standard Battery - SONY NP	Current
34		8.25" x 3.75" x 4.0"	6V Camcorder battery or 120/240 VAC 50/60 HZ, <5 w	Current
81		10.3"L x 4.5"W x 3.8" H total, 8.3"L x 4.5"W x 3.3"H came	6VDC, battery operation >2 hours with 4.5 AH Camcor	Current
24		10.2"Wx14.8"Hx7.2"D	28 VDC nominal, 16 VDC-32 VDC operating. Typical	2nd Quarter 1997 Full Production, Currently in
82		5.3" x 9.7" x 2.5"	<5 watts, 2 hour life with 6 VDC Camcorder battery, A	Current
35		9" Diam. x 24"L	<15 Watts @12VDC	Current
36		6" x 12" x 14"		Current
43		Weapon Mounted, Individual and/or Crew Served		Current
31		Weapon Mounted		Low Rate Production 1995, Full Production 19
42		Picture-http://www.cerf.net:80/hac/products/hire.htm		Current production since 1991. Second gener
37				Testing in 1996 for M2A3 and M1A2, Decisio
71				Currently Fielded

121

Index	Tech. Category	Det./ Acq.	Vehicle Types	Company
75	Laser	Acq	All	
74	Laser	Acq	All	Cadillac Gage Textron (P)
41	Laser	Acq	All	Hughes
7	Laser	Acq	All	Hughes Aircraft
72	Laser	Acq	All	Navy
16	Laser	Acq	All	Radio Corp. et al.
70	Laser	Acq	All * Handheld	
76	Laser	Acq	All * Handheld	
77	Laser	Acq	All * Handheld	RCA
86	Laser	Det & Acq.	All * Handheld	Leica
47	LIDAR	Det	All	Orca Photonics
46	LIDAR	Det	All	Science and Engineering Services Inc.
59	Mine	Det	All	A&S Company
56	Mine	Det	All	GDE - P.O.C. Ray Garriot (619) 592-5567
8	Mine	Det	All	Jaycor
58	Mine	Det	All	Science Applications International Corp., Humanitarian Demining BAA, US Army CECOM (NVESD)
28	Mine	Det	All * Handheld	Schiebel Instruments, Inc.
21	Mine	Det	All * Man Portable	P.O.C. Mr. Mark Locke, DSN 654-2418, COMM 703/704-2418
57	Mine	Det	Med, ?LW, SLW?	DARPA, LLNL, NRaD, SAC, SCC, TRA, Univ. of Hawaii
68	Mine	Det	Med, ?LW, SLW?	U.S. D.O.D. ESTCP
61	Mine	Det & Acq	Med, ?LW, SLW?	Martin Marietta
87	Multi - A, BC, M, S, V, W	Det	All * Man Portable	DARPA, CMO, AF, Marines, USSOCOM, USCENTCOM
14	Multi - A, Data, IR, Las, V	Det & Acq	Med, ?LW, SLW?	Dismounted BattleSpace Battle Lab - IEW, ASM
13	Multi - A, IR, M, S	Det	All	Lockheed Martin Control Systems
88	Multi - Data, IR, N, V	Det	All * Man Portable	Dismounted Battlespace BattleLab - IEW
38	Multi - IR, Las, V	Det & Acq	All	P.O.C. Maj. Byrnside, DSN 654-2915, COMM703/704-2915
80	Multi - IR, Las, V	Det & Acq	All	System Planning Corporation
89	Multi - IR, N	Det	All	Dismounted Battle Lab
25	Multi - IR, N	Det	All * Handheld	NightVision Engineering & Manufacturing, L.L.C.
85	Multi - IR, N, R, SIGINT, V	Det & Acq	Med, ?LS, SLW?	Motorola
83	Multi - IR, N, V	Det & Acq	Med, ?LW, SLW?	Boeing (P), Hughes (Sub)
97	Multi - IR, R	Det & Acq	All	Alliant Techsystems
92	Multi - IR, R	Det & Acq	All	Thomson-CSF (France), Vision Abell (Australia)

122

Index	Product Name	Product ID	Weight
75	Light Armored Vehicle Air Defense CO2 laser rangefinder	LAV-AD	
74	Light Armored Vehicle 105 mm gun laser range finder	LAV-105	
41	Eyesafe Laser with Integrated Telescope Equipment	ELITE	
7	Modular Universal Laser Equipment (MULE)	AN/PAQ-3	42lbs (19.07 kg) Daytime; 1
72	Compact Laser Designator	CLD	Lightweight
16	Laser Rangefinder (Infrared Observation Set)	AN/GVS-5	5 lbs (2.27 kg) w/battery
70	Laser Target Designator	AN/PAQ-1 (LTD)	Handheld
76	Tactical Laser Pointer	LPL-30	Man Portable
77	Mini Laser Rangefinder	AN/PVS-X (MLRF)	lightweight
86	Leica Enhanced Laser Rangefinder		Handheld Binoculars
47	Trasnportable Raman Lidar System		
46	Micro Pulse Lidar		50 kg
59	Mine Detecting Set	AN-19/2	Man Portable Detector
56	Integrated GPR/EMI Mine Detection		Man-portable
8	Standoff Mine Detection Radar System	SMDRS	Current Prototype 200 lbs,
58	Thermal Netron Analysis Mine Detector	TNA Mine Detector	
28	Metallic Mine Detector	AN/PSS-12	8.5 lbs (3.8 kg) w/o case, 1
21	Close in Man Portable Mine Detector	CIMMD (ATD)	30 lbs for IRTI, 26 lbs for G
57	Hyperspectral Mine Detector	HMD	
68	Multi-Sensor Towed Array Detection System	MTADS	Vehicle Towed
61	Off Road Smart Mine Clearance	ORSMC	Remote HMMWV integrate
87	Unattended Ground Sensor ATD	UGS	Expected - Manportable
14	Hunter Sensor (Surrogate) Suite ATD	HSS, HS3	HMMWV Integrated - Appr
13	Improved - Remotely Monitored Battle Field Sensor System (I-REMBASS	AN/PSQ-7(V)	
88	Remote Sentry ATD		Expected - Manportable
38	Lightweight Laser Designator Rangefinder (LLDR)	LLDR	30 lbs, broken into 2- 15 lb l
80	Hunter Sensor Surrogate Vehicle same as Magic Warrior and Night Stalk		
89	Own The Night	Includes AN/PVS-7B (NVG), AN/PAS-13 (TWS), AN/VAS-5 (DVE)	
25	Night Roamer Pocket Scope Model B		14.7 oz
85	Joint Surveillance Target Attack Radar System, Light Ground Station Mo	Joint STARS, LGSM	HMMWV Portable with Trai
83	Avenger Infrared System	AN/VLR-1	2568 lbs (1165.87 kg) - ove
97	Dual-Mode MMW/Uncooled IR Seeker	MMW/IR SADARM (spinoff)	Lightweight
92	RAdar Plus Thermal Observation and Recognition system	RAPTOR	Lightweight, Modular

124

Index	Unit Price	Space Reqs	Power Reqs	Availability
75				Currently Fielded
74				Currently Fielded
41				Current
7	$218,000	Man-portable, tripod mounted or shoulder fired	24 volt DC, NI-CD, Run time 10 minutes, Recharge tim	Currently Fielded
72		Small		Currently Fielded
16	$5370	9"L x 8"W x 4"H	24 volts (battery or vehicle power)	Currently Fielded
70		Handheld	Battery Operated	Currently Fielded
76				Currently Fielded
77		handheld		Currently Fielded
86		Handheld Binoculars		Prototype - Experimentation with Specail Purp
47				Current
46		Controller and Display: 49 x 23 x 51 cm, Tranceiver: 41 x	115V/60 Hz, ~5A	Curmet IR&D
59	$4899.00		Dry Cell Batteries (IEC standard size LR20 or ANSI sta	Current
56				
8		Prelim Specs: System 2 cu.ft., Antennas 6 cu. ft.	Prelim Specs: 100 watts	Prototype successfully field tested February 19
58		Metal Array -2 x 2 meter array for prototype + sensors		Prototype
28	$1196	Hand Held	4 - 1.5 V batteries, 70 hour operating time	Current
21		Carried - Each system is a backpack and helmet configur		1996 Demonstration
57				
68				Prototype
61				1996 ACTD -Prototype Expected 1997
87	Throw Away	"Miniature"	Battery	ATD FY97 Start, 3 year funding
14		HMMWV Integrated - Approximate - for Prototype		1998 Prototype
13		6' x 6'x 6'	Lithium or Alkaline Batteries	1996
88	Max<114.6K, Go		Battery Operated, Remotely Activated	ATD FY93 Start, Delivery of Prototype 1Q97,
38				Demonstrator unit scheduled for 1st quarter 19
80	< 500k productio		Standard Issue Batteries, Generator, and Vehicle Elect	Current Prototype
89				NVG Currently fielded, TWS and DVE full rate
25	$1060 +	5"L x 1.75"W x 2.625" H	3 V battery, 25 hour life	Current
85		HMMWV Portable w/Trailer		Currently Fielded
83	$617,000 (per sy	182" L x 104" H x 87" W (4.62m x 2.64m x 2.21m) - overal		Current
97		6.3 inches squared transceiver, plus antenna which attach		Current
92				Developmental - 1996

Index	Tech. Category	Det./ Acq.	Vehicle Types	Company
78	Multi - IR, V	Acq	All	
10	Multi - IR, V	Det	All * Weap. Mount	Texas Instruments
45	Multi - IR, V	Det & Acq	All * Handheld	Texas Instruments
9	Multi - IR, V	Det & Acq	Med, ?LW, SLW?	Texas Instruments, Systems Group, Defense Systems and Electronics
6	Multi - IR/Las, R(MTI, MM)	Acq	Med, ?LW, SLW?	Mounted Battlespace BattleLab - IEW, ASM
91	Multi - Lad, RSTA, V	Det & Acq	Med, ?LW. SLW?	ARPA, DOD, DOE, DOT
90	Multi - Las, N	Det	All	Dismounted Battlespace Battle Lab - Stingray
55	Multi - M, R, S	Det	All	Stano
11	Multi - N, V	Det	All	Ft. Hood/Lewis
63	Night Vision	Acq	All * Weap. Mount	Rapid Acquisition Targeting System
84	Night Vision	Acq.	All * Weap. Mount	Hughes
30	Night Vision	Det	All * Handheld	IMO,VARO,ITT, Litton
29	Night Vision	Det	All * Handheld	ITT, Litton
27	Night Vision	Det	All * Helmet Mount	Litton
32	Night Vision	Det & Acq	All	IMO, VARO
17	Night Vision	Det & Acq	All	Trijicon
44	Night Vision	Det & Acq	All * Weap. Mount	Hughes
33	Night Vision	Det & Acq	All * Weap. Mount	IMO, VARO
26	Night Vision	Det & Acq	All * Weap. Mount	NightVision Engineering and Manufacturing
96	Radar	Acq	All	Thomson-CSF
93	Radar	Det	All	Thomson-CSF
18	Radar	Det & Acq	All	Eaton/Telephonics, AIL Systems, subsidiary of EATON
94	Radar	Det & Acq	All	Thomson-CSF
22	Radar	Det & Acq	Med, ? LW, SLW?	P.O.C. Mr Larry Bovino, DSN 995-4225, COMM 908/544-4226
20	Radar	Det & Acq	Med, ?LW, SLW?	Hughes Aircraft Company, Grumman upgrade with Radstone technology
19	Radar	Det & Acq	Med, ?LW, SLW?	Hughes Aircraft Company, Grumman upgrade with Radstone technology
5	Radar - MW	Det	All	TRW Space and Electronics Group
4	Radiation	Det	All	AIL Systems, Consolidated Edison Company of NY, Industrial Quality Inc, and PMX
23	UltraViolet	Det	All	Littlemore Scientific
15	Visible	Det	All	IMO,VARO
95	Visible	Det	All	Thomson-CSF

Index	Product Name	Product ID	Weight
78	Target Designator	TD-100	Man Portable
10	Target Acquisition System	AN/PXX-X TAS	Man Portable
45	Nightsight 15 & 9 degree lenses	W1000, H1000	15deg: 3.1 lbs, 9deg: 3.4 lb
9	Improved Target Acquisition System	ITAS	
6	Target Acquisition ATD		
91	Unmanned Ground Vehicle/Demo II	UGV/Demo II	HMMWV Integrated
90	Target Location and Observation System	TLOS	Lightweight - M16 mounted
55	Platoon Early Warning System	AN/TRS-2	23 lbs
11	Lightweight Video Reconaissance System	LVRS	Out Station (Reconaissanc
63	RATS 635 Visible Light	RATS 635	
84	Elcan Blackcat		Lightweight, rifle mounted
30	Night Vision Goggles	AN/PVS-5	30 oz (.85 kg)
29	Night Vision Goggles	AN/PVS-7B	24 oz (.68 kg)
27	M982 /M983 Monocular with Gen II / Gen III image intesifier tube	M982/M983	Helmet, Face Mask Mounte
32	Crew Served Weapon Night Sight	AN/TVS-5	8 lbs (3.63 kg)
17	Advanced Combat Optical Gunsight ACOG	TA01, NSNM4A1	Weapon Mounted/Aluminu
44	Stinger Night Sight	AN/PAS-18	Man Portable
33	Individual Weapon Night Sight	AN/PVS-4	4lbs (1.818 kg)
26	Coyote II Weapon Sight		1 lb 14 oz
96	Flycatcher	Flycatcher	
93	Ground Surveillance Radar	Rasit - G	Lightweight
18	Modular Lightweight Battlefield Surveillance System	AN/PPS-5	125 lbs (currently trying to r
94	Ground Surveillance Radar	RB 12 B	Lightweight
22	Bistatic Radar For Weapons Location	BRWL (ATD)	Towed Reciever
20	Firefinder Artillery Locating Radar	AN/TPQ-37	Heavy
19	Firefinder Mortar and Artillery Locating Radar	AN/TPQ-36	Heavy
5	Passive Millimeter-Wave Camera	PMMW Camera	
4	Gamma Ray Imaging System (GRIS)	Gamma Cam	Man-portable
23	763 Crawford Monitor		14 oz (390 g)
15	M49 Telescope		2.75 lbs (1.25 kg)
95	Mobile Optronic Surveillance System	MOS2	Lightweight

126

Index	Unit Price	Space Reqs	Power Reqs	Availability
78				Currently Fielded
10		Weapon Mounted		Production 3rd Quarter 1997
45		15 deg: 3.8"Wx4.3"Hx12.9"L ; 9 deg: 4.3"Wx4.6"Hx14.3"	nominal: 4-9 VDC Battery, operating 8 VDC - 40 VDC,	Current
9				
6				4th Quarter 1997
91				Demo II performed June 1996
90		Weapon Mounted		Fielded 1Q96
55	$995	Fits within a carrying bag	Operates of 9 VDC batteries	Current
11		Out Station (Reconaissance Vehicle) 6"x24"x36"		1996 Prototype
63		.48"W x .40"H x .56"L	6VDC, PX28L Battery Life	Current
84			3.1 or 6 power (VDC?)	Current
30	$5111	6.5"L x 6.8"W x 4.7"H (16.51cm x 17.27cm x 11.94cm)	2.7V Mercury Battery (BA-1567/U, BA-5567/U, BA-305	Current
29	$6000	5.9"L x 6.1"W x 3.9"H (14.99cm x15.49cm x 9.91cm)	Mercury Ni-CD or Li 2.7 V batteries (BA-5567 or AA ce	Current
27	$5000 +			Current
32	$4,005	15"L x 6"W x 6"H (38.1cm x 15.24 cm x 15.24cm)	2.7V Mercury Battery (BA-1567/U, BA-5567/U, BA-305	Current
17	$706-$1102			Current
44		Weapon Mounted		Current
33	$4815	12"L x4"W x 4.5"H (30.5cm x 10.2cm x 11.4cm)	2.7V Mercury Battery (BA-1567/U, BA-5567/U, BA-305	Current
26	$1500 +	8.25"L x 8.25"W x 2.5"H	3 V battery, 25 hour life	Current
96				
93				Currently Fielded
18	Upgrade1/9th of	Carried, Tripod or Vehicle Mounted Adaptations, Modular	24 VDE - rechargeable batteries (BB-622) or external p	Only Available through repair of existing - mod
94				
22		Towed Receiver		1996
20		Currently Fielded on an M035 series truck, M-1048 Trailer	MEP-115A 60 kwatt, 400 hertz Generator Set	Last fielded in 1992
19		Currently Fielded on one M-35 2 1/2 ton Truck, and an M1	2 MEP-112s 10 kwatt, 400 htz, diesel generators	Current
5				September 1998
4	$50-75k	(picture in URL)		September 1995
23		7.7" x 3.9" x 1.6" (195mm x 100mm x 40mm)	Alkaline or Mercury 8 -9V PP3 type or External 7-16V	Current
15	$511	13.5 inches	None	Current
95				

Armor Technology Alternatives

NIJ class	Threat, Example	Type of Armor	lbs/ft^2	\$/ft^2	thickness (in)
II	357 mag. JSP,	Fiberglass composite	3	30	$^1/_3$
	9mm FMJ	Glass+Polycarbonate (transparent)	7	60	$^{11}/_{16}$
IIIA	44 mag. SWC	Ballistic steel	5.25	16	$^1/_8$
		Kevlar composite	1.6	80	$^1/_4$
		Spectra composite	1.25	65	$^1/_4$
		Glass+Polycarbonate (transparent)	15	90	$1\,^1/_3$
III	7.62x39 FMJ,	Ballistic steel	11	33	$^1/_4$
	81mm mortar fragments	Kevlar + alumina	7	350	$^3/_4$
		Spectra composite	4.75	250	1
		Glass+Polycarbonate (transparent)	18.25	125	$1\,^2/_3$
IV	5.56x45 FMJ,	Ballistic steel	16	48	$^3/_8$
	7.62x51 AP,	Spectra + alumina	6.5	350	1
	30-06 AP,	Spectra + Boron carbide	5.5	400	1
	anti-personnel mine	Glass+Polycarbonate (transparent)	25	200	3

JSP- jacketed soft point
FMJ- full metal jacket
SWC-semi wad cutter
AP- armor piercing

APPENDIX I

Firepower Survey Results

Category	Weapon	Caliber	Gun Weight (lb)	Range (meters)	Gun Size (in)	Comments
Personal	M16A1/A2 Rifle	5.56 mm	8.9 lb including 30 round loaded magazine	274 (this short range is the users biggest complaint)	38.9" long with flash suppresser 36.4" barrel length	700 - 900 rpm rate of fire. Over 5 million in use. Gas operated, optional bipod, telescope and night sight
Personal	M9 handgun	9 mm	2.6 lb (loaded)	50	8.6" long 4.92" barrel	390 m/s muzzle velocity 15 round magazine
Personal	M79 Grenade Launcher	40 mm	6 lb empty 0.61 lb projectile	400 m (max) 350 m (area targets) 150 m (point targets)	29" long 14" barrel	76 m/sec muzzle velocity. Single shot. Replaced by M203 grenade launcher.
Personal	M203 Grenade Launcher	40 mm	3 lb launcher	350 m (area) 150 m (point) 400 m max		Attaches to the M16 rifle. Approx cost = $600.
Personal	MP-5N	9 mm	7.44 lb with a 30 round mag	100 m	26" extended	For special purpose forces. 800 rpm Approx cost = $800.
Personal	M249 Squad Automatic Weapon (SAW)	5.56 mm	15.5 lb empty 22 lb with 200 round magazine	1,300 m	39.4" long 18.5" barrel	750 rpm. 924 m/s muzzle velocity

Category	Weapon	Caliber	Gun Weight (lb)	Range (meters)	Gun Size (in)	Comments
Secondary	M60 Machine Gun	7.62 mm	23 lb with bipod 39.6 lb with tripod	900 (bipod) 1,800 (tripod)	43.3" long 22" barrel	550 rpm cyclic rate, 200 rpm automatic. Gas operated. Uses 100 round ammo belts. Barrel changed after 500 rounds. Can mount on vehicles with the M142 mount. Being replaced by the M240G.
Secondary	M240G Medium Machine Gun	7.62 mm	24.2 lb	1,800 m (tripod mounted)	47.5" long	650 - 950 rpm cyclic rate of fire. 100 rpm sustained. Approx cost = $6.6K Can be pintle mounted for vehicular applications.
Primary	M2 HB Machine Gun	12.7 mm (0.5")	83.3 lb 127.8 lb with tripod	6,830m max	65.07" long 45" barrel	Gas operated. Fires ball, tracer, armor piercing and incendiary rounds.
Primary	MK19-3 Grenade Launcher	40 mm	72.5 lb	1,500 m (point targets) 2,200 m (area targets)	40.4" long	350 rpm, gas operated. 240 m/sec muzzle velocity. 5 m casualty radius. Can penetrate 2" of armor at 2,200 m range.

/33

Category	Weapon	Caliber	Gun Weight (lb)	Range (meters)	Gun Size (in)	Comments
Primary	M29A1 mortar	81 mm	28 lb barrel 25 lb baseplate 40 lb bipod 115 lb total with sight	4,700 m		40° to 85° elevation. +/- 4° traverse. 30 rpm for one minute, 4 - 12 rpm sustained. Being replaced by the M252.
Primary	M252 Mortar	81 mm	35 lb assembly 26 lb bipod 25.5 lb baseplate 2.5 lb sight 89 lb total	5,700 m		33 rpm max rate of fire, 16 rpm sustained. 45° to 85° elevation. Approx cost = $25K.
Primary	M224 Lightweight Mortar	60 mm	46 lb total	3,500 m		Indirect fire weapon. Replaced the M29 in non-mechanized infantry. Often used with the AN/GVS-5 hand held laser range finder. 30 rpm maximum, 20 rpm sustained. Approx cost = $11K.
Missile Launchers	M72A2 Light Anti-Tank Weapon (LAW)	66 mm	4.75 lb complete 2.2 lb rocket.	325 m	20" rocket length 25.7" launcher 35" extended	145 m/sec muzzle velocity. Shoulder fired. HEAT round can penetrate 11.8" of armor. Being replaced by the AT-4 light weight multi-purpose weapon.

Category	Weapon	Caliber	Gun Weight (lb)	Range (meters)	Gun Size (in)	Comments
Missile Launchers	Lightweight Multi-Purpose Weapon, AT4	84 mm	14.6 lb complete	300 m	39.7" long	Single shot, throwaway, squad anti-tank rocket. 290 m/s muzzle velocity Getting old, cannot defeat the latest Soviet armor.
Missile Launchers	Advanced Anti-Tank Weapon System-Medium (AAWS-M)		45 lb complete 32 lb missile	2,000 m		Fire and forget anti-tank missile. Imaging infra-red seeker.
Missile Launchers	FIM-43A Redeye		29 lb complete 18 lb missile	3,300 m	48" L x 2.75" dia	Shoulder fired, infantry surface-to-air missile. Initial optical aiming, IR homing. Mach 2.5 flight speed. No IFF, must wait for aircraft to attack, then fire at their exhaust. Guidance is vulnerable to IRCM. Flight speed is just enough to catch existing attack aircraft.
Missile Launchers	FIM-92A Stinger		35 lb complete 24 lb missile	5,000 m	60" missile x 2.75" diameter	Portable air defense missile. Passive IR homing, includes IFF. Mach 2 flight speed. Replaced the Redeye. Used in HMMWVs, carries 8 missiles.

Category	Weapon	Caliber	Gun Weight (lb)	Range (meters)	Gun Size (in)	Comments
Missile Launchers	TOW-2B BGM-71		46.1 lb launch weight	3,750 m	45" - 75" long x 6" diameter	Heavy anti-tank missile. Used in HMMWVs, carries 6 missiles. 1003 km/hr flight speed. Optically tracked (day or night)
Missile Launchers	Dragon M47 FGM-77A		24.4 lb launch weight 5.4 lb shaped charge warhead	1,000 m	29.3" long x 4.5" diameter	Infantry anti-tank/assault missile. 370 km/hr flight speed. Designed as a medium range complement to the TOW. Throw-away launch tube.
Missile Launchers	Shoulder Launched Multipurpose Assault Weapon (SMAW)	83 mm	16.6 lb carry weight 30.5 lb ready to fire	250 m (1 x 2 m target) 500 m (tank sized target)	29.9" carry length 54" ready to fire	Unit cost approx $13K. Consists of the MK153 launcher, MK3 encased HEDP rocket, MK6 encased HEAA rocket and the MK217 spotting rifle cartridge. Uses the MK42 day sight and the AN/PVS-4 night sight.

Notes:

1. Deadeye-40/50 is a remote controlled, stabilized mount for use with the MK19 and M2 HB weapons. It uses 24Vdc, is Mil-Std-1275 compatible, requires 100 watts for average operation (50 watts standby) and has day and night sight capabilities. Max dimensions are 65.5" long x 32" wide and weighs 243 pounds. Weight is 439 pounds including the M2 HB machine gun and ammo.

2. The MK93 is a dual purpose, soft mount for the MK19 Grenade Launcher and M2 HB Machine Gun. The MK93 is designed for use with either a tripod or a vehicular mount (using the MK175 pintle pedestal). The MK93 requires no external adapters or tools to mount either weapon system, making change-overs much easier. The use of a soft mount improves the accuracy of the M2 Machine Gun by attenuating the recoil. The MK93 consists of a carriage and cradle assembly, train stop bracket, ammunition can holder, a bolt-on small pintle, a bolt-on large pintle, and stowage bar assembly. It weighs 30 pounds, measures 6.8" high x 10" wide x 22" long and costs about $3.2K.

3. A typical RSTA mission would most likely employ the following weapons:

   <u>Personal:</u> Each person wearing an M9 handgun on their belt, an M16 machine gun with an M203 attachable grenade launcher in readily accessable storage.

   <u>Secondary:</u> The vehicle will have M240G machine guns mounted on both right and left doorposts.

   <u>Primary:</u> The vehicle will most likely require a universal mount to accomodate either the MK19 or the M2 HB machine gun.

MINES

Anti-personnel mines are designed to kill or maim personnel who happen to walk over the buried device. They are very inexpensive ($3 to $30 a piece) and are unfortunately in wide spread use. The fuse may incorporate a tripwire, an anti-handling device or some form of electronic sensor. Anti-personnel mines are equipped with 10-250 g of explosive, and detonate under pressures ranging from 0.5 to 50 kg. There are roughly 360 types of anti-personnel mines available, produced in some 55 countries, and can be divided into two (more or less) distinct groups: blast mines and fragmentation mines.

Blast mines are surface or sub-surface laid, activated by pressure and rely mainly on blast for their effectiveness. Secondary fragmentation injuries are possible as the mine casing or surrounding dirt or gravel is blasted at the victim. Modern anti-personnel blast mines have a plastic watertight casing; only the detonator, springs and strikers are metal, making them difficult to detect and clear.

When a fragmentation mine explodes, shrapnel, pre-cast fragments or steel balls are projected outwards over a given radius (10-50 m) at approximately twice the velocity of a bullet, producing puncture wounds, blinding and death. Fragmentation mines can be divided into three sub-groups.

(a) Stake mines: in order to increase the shrapnel effect, these mines are mounted on stakes to raise them above the ground.

(b) Directional fragmentation mines: these mines fire small fragments in a predetermined direction. The most notorious of these is the Claymore mine.

138

(c) Bounding mines: a small propelling charge first lifts the mine to about stomach height before the main charge explodes, making it much more lethal (the kill rate for those triggering the mine is 100%) and shooting the fragments over a much wider area.

It is unlikely that any LSV applications would be required to carry and deploy anti-personnel mines as President Clinton announced four unilateral actions against there use. First, he directed the U.S. military immediately stop using "dumb" anti-personnel land mines -- those that remain active until detonated or cleared. The only exception is on the Korean Peninsula, where he judged the risk to U.S. interests was too great. U.S. forces will rid the arsenal of more than 4 million anti-personnel mines by 1999. Second, the United States reserves the right to use "smart" anti-personnel mines, which self-destruct, because these mines will save the lives of U.S. service members in some battlefield situations. Third, the president directed DoD to examine tactical alternatives to mines. Finally, he directed DoD to expand efforts to develop better mine-detection and mine-clearing technology.

Anti-tank mines usually contain between 2 and 9 kg of explosive and are activated by pressures between 100 and 300 kg. Anti-tank mines are less dangerous to civilians than anti-personnel mines because they are not usually detonated by pedestrians. A typical anti-tank mine uses 5.4 kg (12 lb) of TNT and is buried a few inches below the surface. Modern anti-tank mines are triggered by seismic fuses which can differentiate between fried or foe signatures.

State of the art mine technology includes:

1. <u>Remotely delivered mines</u> - First used on a large scale in Viet Nam, remotely delivered mines (also known as scatterable mines) are strewn in large quantities from aircraft or helicopter underwing pods or from artillery, mortar or rocket warheads. Most scatterable mines are small and many are intended to be dual-purpose anti-personnel/anti-tank devices. One vehicle-mounted mine-scattering system dispenses up to 1,750 anti-personnel mines per minute, while a helicopter-mounted system, is designed to drop 2,080 anti-personnel mines in three to 16 minutes. Unless they are self-destructing or self-neutralizing, it is almost impossible to use them in a manner which complies with Protocol II (Clinton's statement above).
2. <u>Self-neutralization and self-destruction mechanisms</u> - Mines whose fuses incorporate these types of mechanism are commonly referred to as «smart mines», as opposed to the traditional «dumb» or conventional mines. Designed to self-destruct or self-neutralize after a predetermined period, they are held by some to be a viable alternative to the mapping and fencing of minefields. However, they have not yet shown sufficient reliability under battlefield conditions. To provide acceptable protection for the civilian population, the reliability rate of self-destructing and self-neutralizing mines must be 99.6%, that is, the level achieved by humanitarian mine-clearance operations.
3. <u>Anti-handling and anti-disturbance devices</u> - Mines fitted with simple tilt switches which make them explode as soon as they are tilted or moved are already being produced. Thus if a prodder hits the mine during a clearance operation, the mine explodes in the mine-clearers face. Other fuses are designed to detonate the mine if an electronic mine detector is passed over them, or if they are exposed to daylight.

APPENDIX J

VCI Comparison - Tracks vs. Wheels

Tracked vs Wheeled Tradeoff - VCI Comparison; Tracks vs Wheels

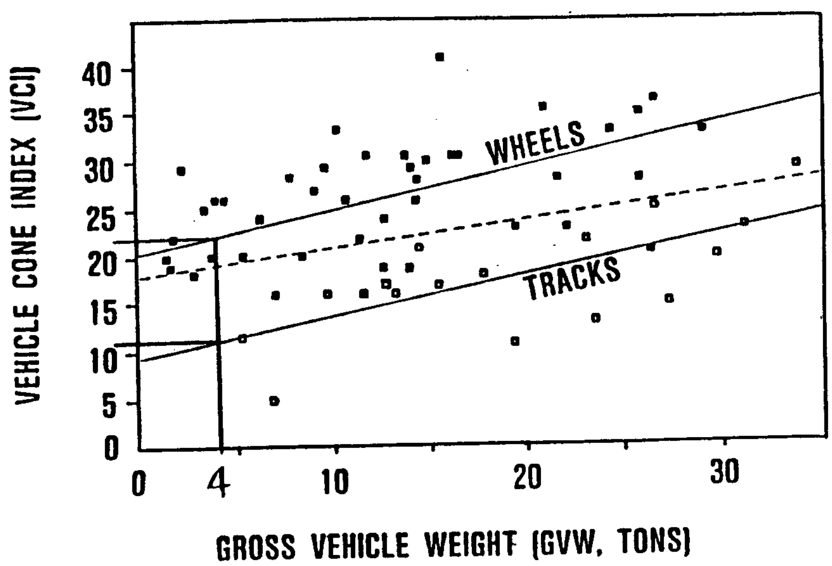


Figure C1. VCI_1 versus GVW, wheeled vehicles without CTI

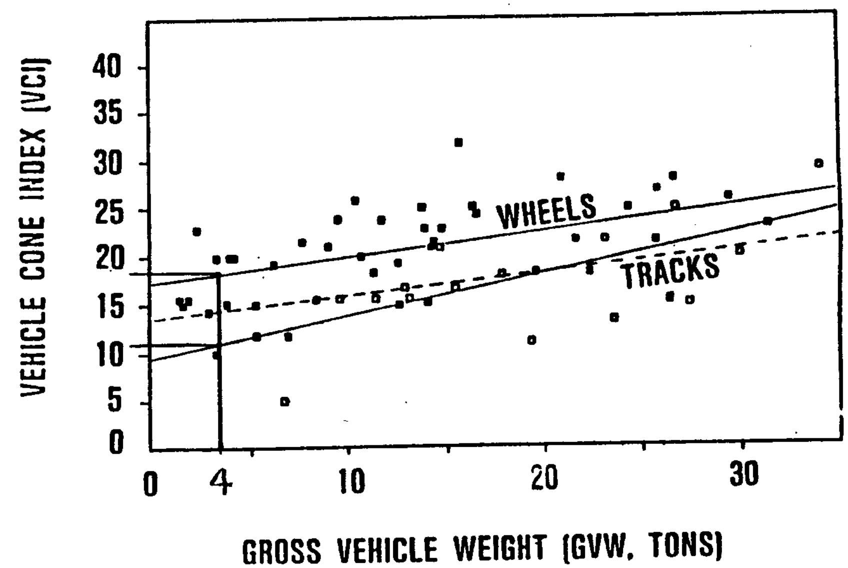


Figure C2. VCI_1 versus GVW, wheeled vehicles with CTI

APPENDIX K

VCI Calculations

Tracked vs Wheeled Tradeoff - VCI Calculations

$$\text{Mobility Index} = \left[\left(\frac{\text{contact pressure factor} \times \text{weight factor}}{\text{tire factor} \times \text{grouser factor}} \right) + \text{wheel load} - \text{clearance factor} \times \text{engine factor} \times \text{transmission factor} \right] + 20$$

Data Source - AMCP 706-356

$$\text{contact pressure factor} = \frac{\text{GVW (lb)}}{\text{tire width x rim dia. x no. of tires}}$$

weight factor = 1.1 GVW > 35,000 lb
1.0 15,000 lb < GVW < 35,000 lb
0.9 GVW < 15,000 lb

tire factor = 1.25 x tire width (in) divided by 100

grouser factor = 1.05 for chains
1.00 without chains

$$\text{VCI} = \left(11.48 + 0.2\,\text{MI} - \frac{39.2}{\text{MI} + 3.74}\right)\left(\frac{.15}{\delta/h}\right)^{.25}$$

Data Source - ADA 297810

where: MI = mobility index
δ/h = tire deflection ratio

$$\text{wheel load} = \frac{\text{GVW (klbs)}}{\text{no. of wheels}}$$

$$\text{clearance factor} = \frac{\text{clearance (in)}}{10}$$

engine factor = 1.0 if hp > 10
1.05 if hp < 10

transmission factor = 1.0 hydraulic
1.05 mechanical

145

Tracked vs Wheeled Tradeoff - VCI Sample Calculations

Surrogate Fast Attack Vehicle has a VCI = 22 (1)

$$MI = \left[\left(\frac{\frac{3500}{11.5 \times 15 \times 4} \times 0.9}{\frac{1.25 \times 11.5}{100} \times 1.00} + \frac{2.75}{4} - \frac{11.75}{10} \right) 1.0 \times 1.05 \right] + 20 = 52.8$$

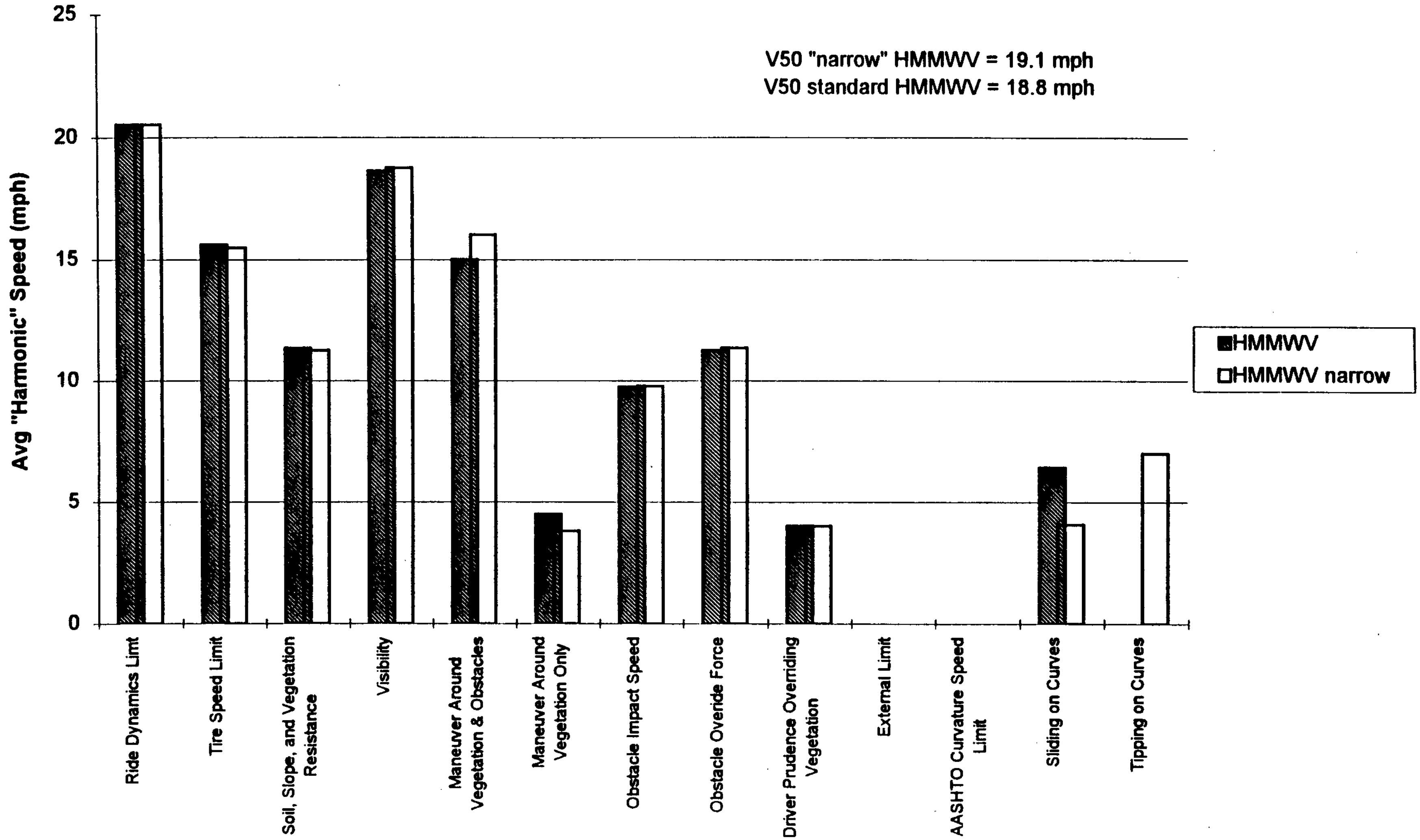
$$VCI = \left(11.48 + 0.2 \times 52.8 - \frac{39.2}{52.8 + 3.74} \right) \left(\frac{.15}{.10} \right)^{.25} = 23.6^{(2)}$$

(1) Results of Mobility Tests on the Surrogate Fast Attack Vehicle
(Technical Report GL-84-9, Table 1, R. Gillespie, September 1984)
(2) Calculations are Conservative

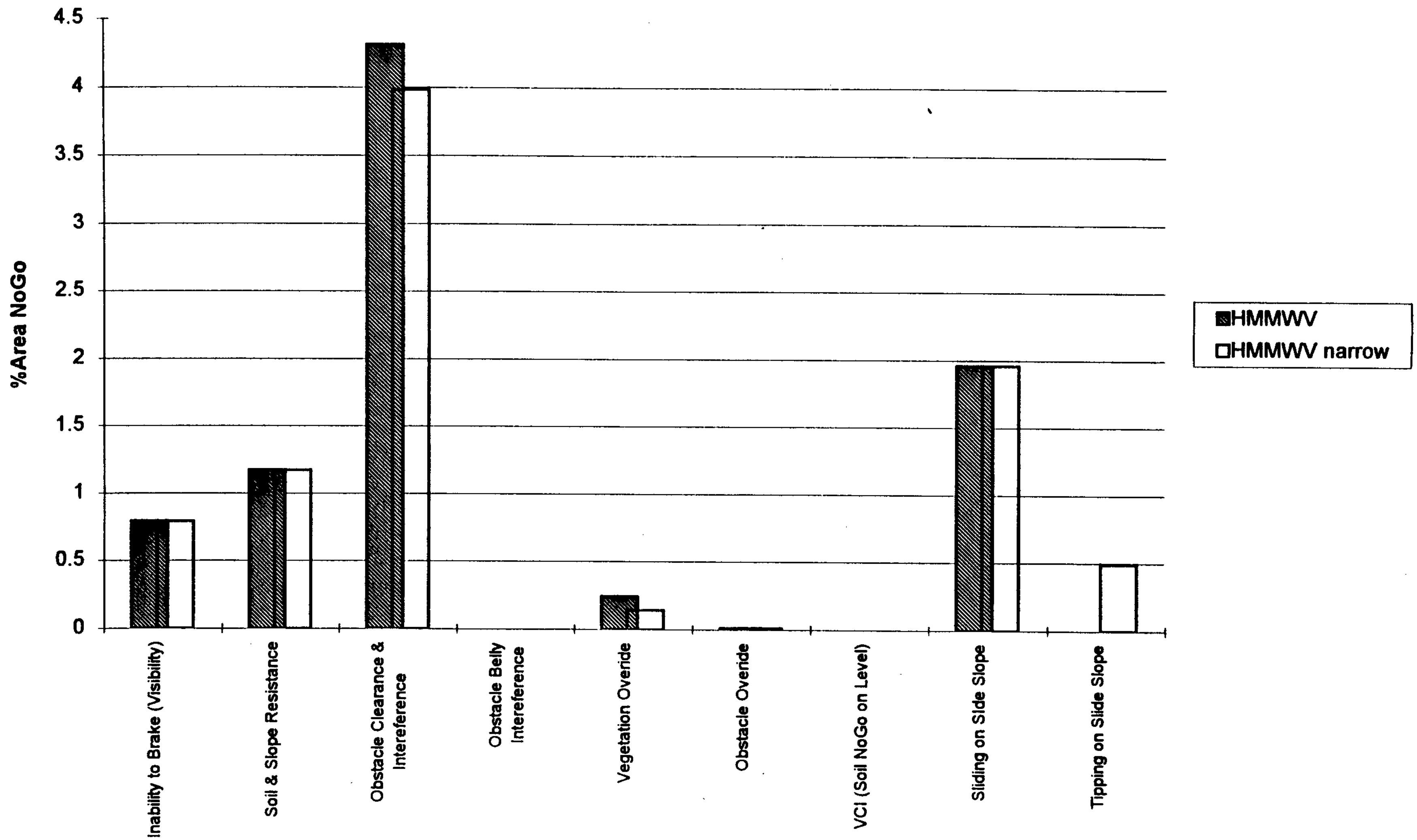
APPENDIX L

Initial NRMM Results

NRMM Study (Lauterbach Terrain)



NRMM Study (Lauterbach Terrain)

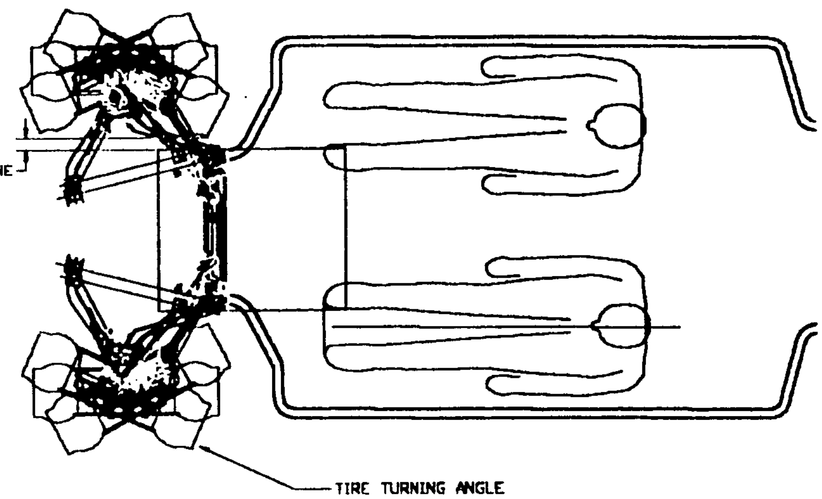


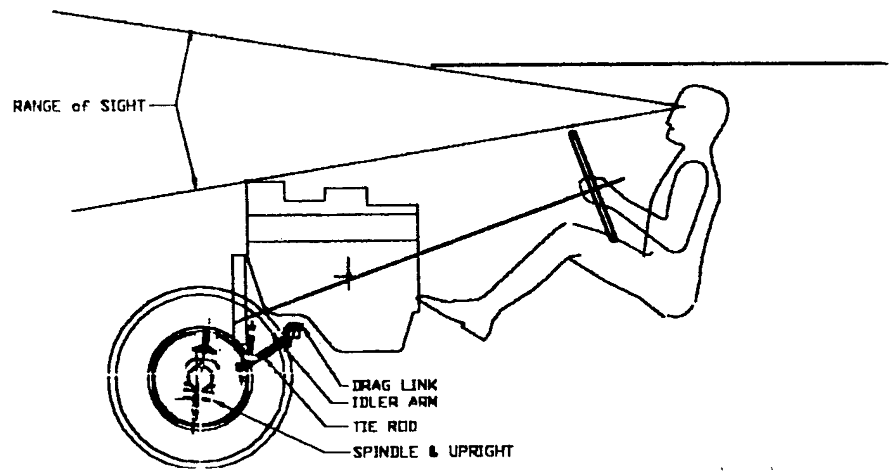
APPENDIX M

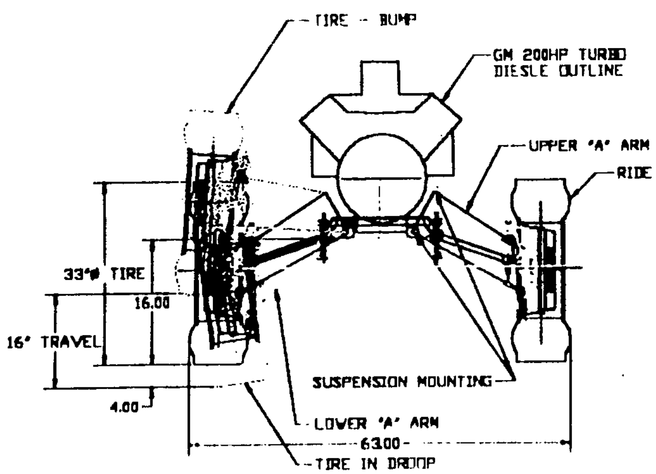
Suspension / Engine Relationships

155

Subsystem Concept Development
Mobility - Standard Suspensions
Suspension/Engine Relationships
Front, Plan & Side Views

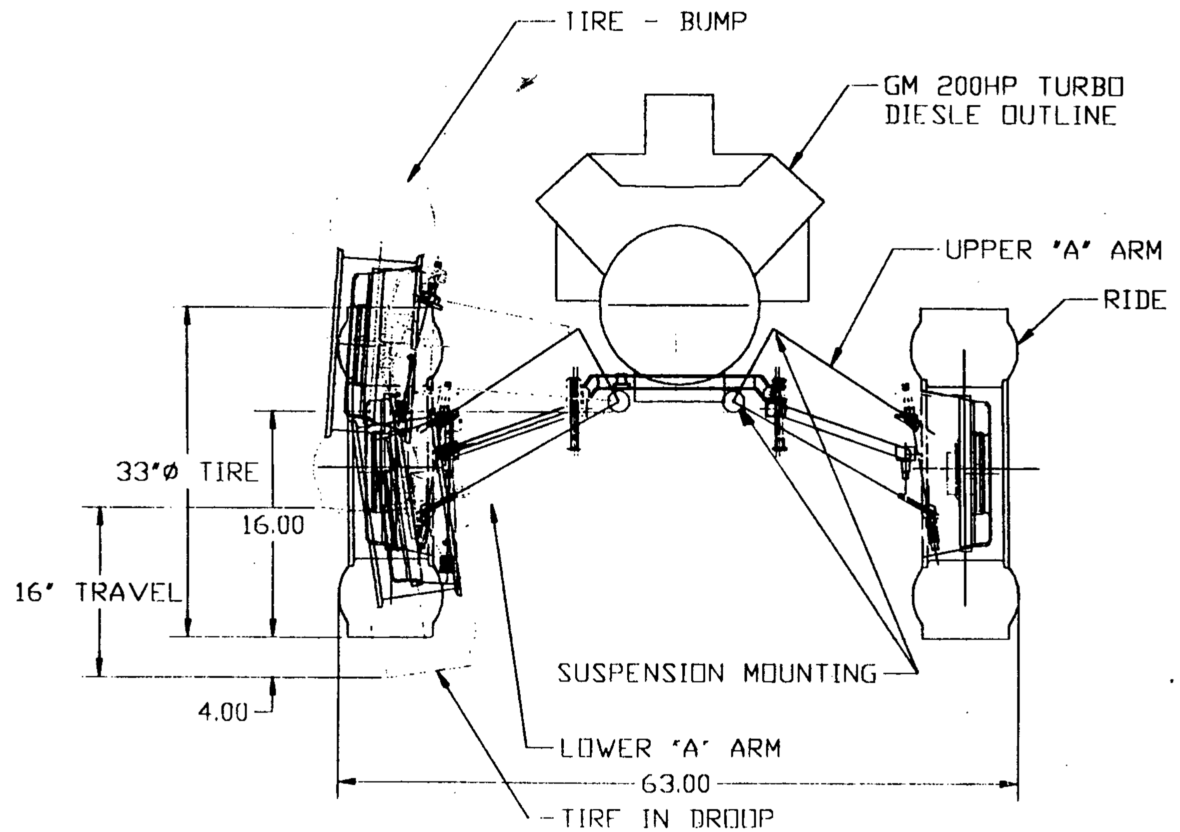




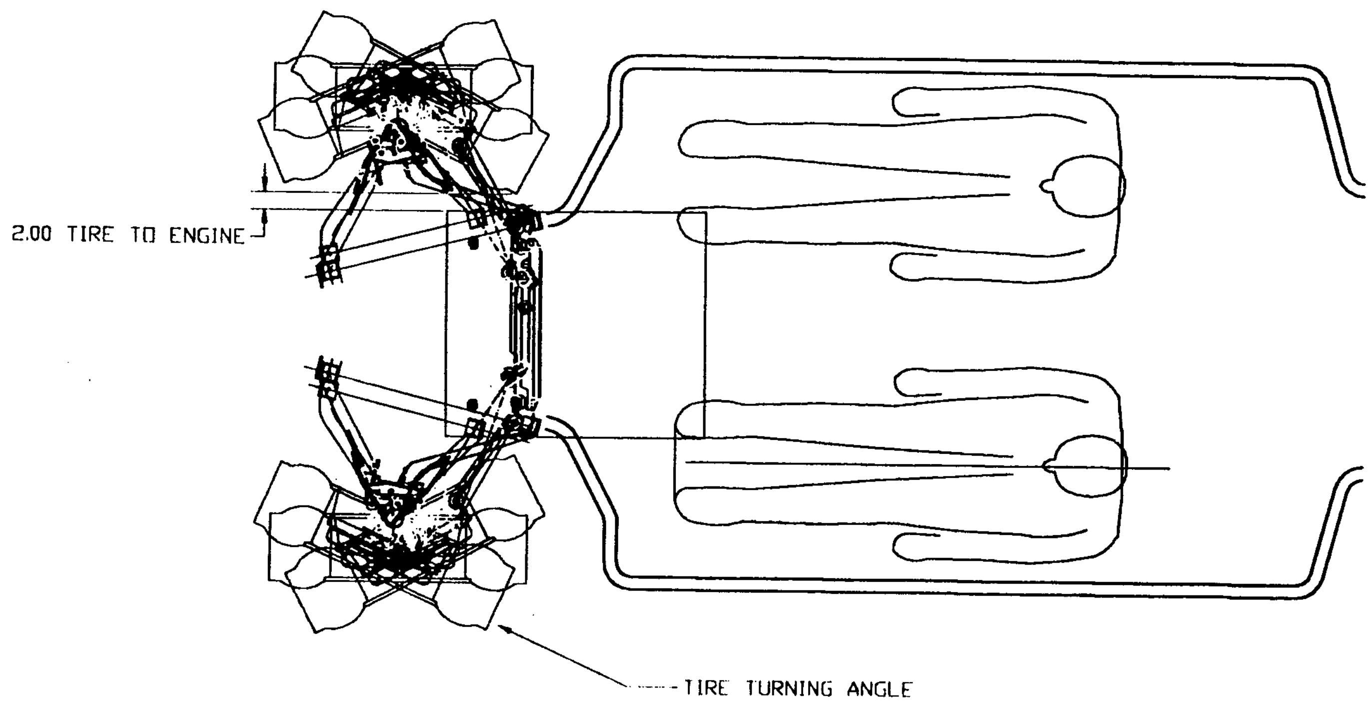


157

Subsystem Concept Development
Mobility - Standard Suspensions
Suspension/Engine Relationships
Front View



Subsystem Concept Development
Mobility - Standard Suspensions
Suspension/Engine Relationships
Plan View

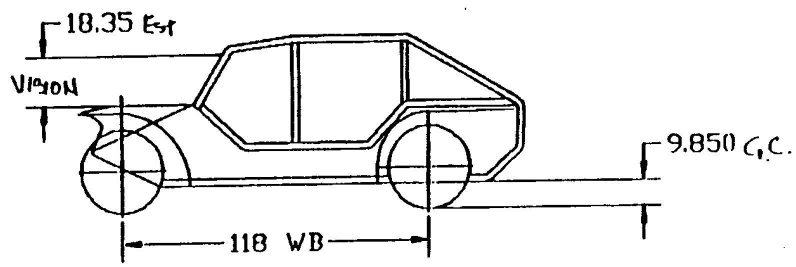


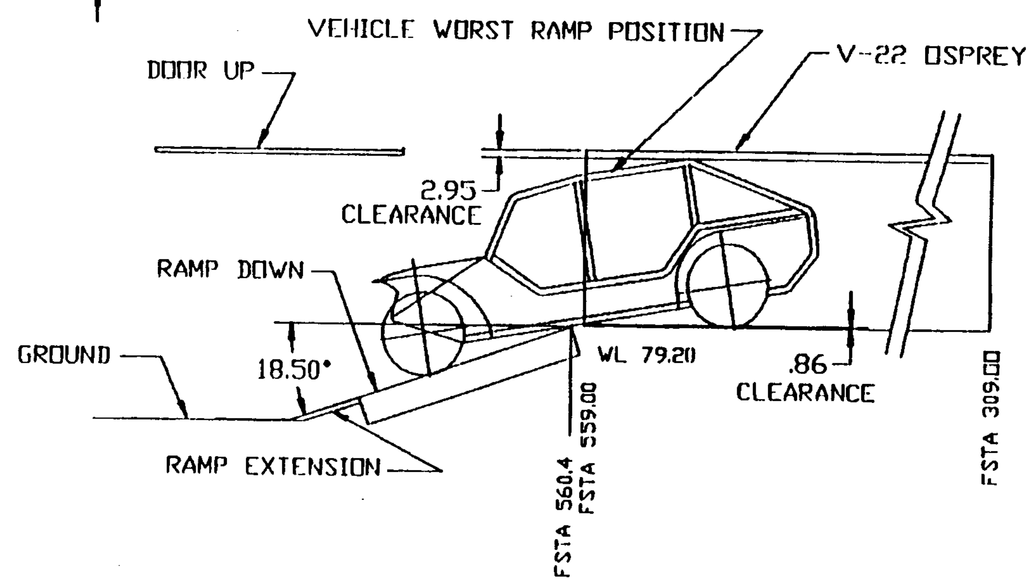
APPENDIX N

Wheel Base Assessment

Initial Vehicle Assessment - Wheel Base

- 118" Wheel Base was chosen to be compatible with our retractable suspension approach based on 10" ground clearance





163

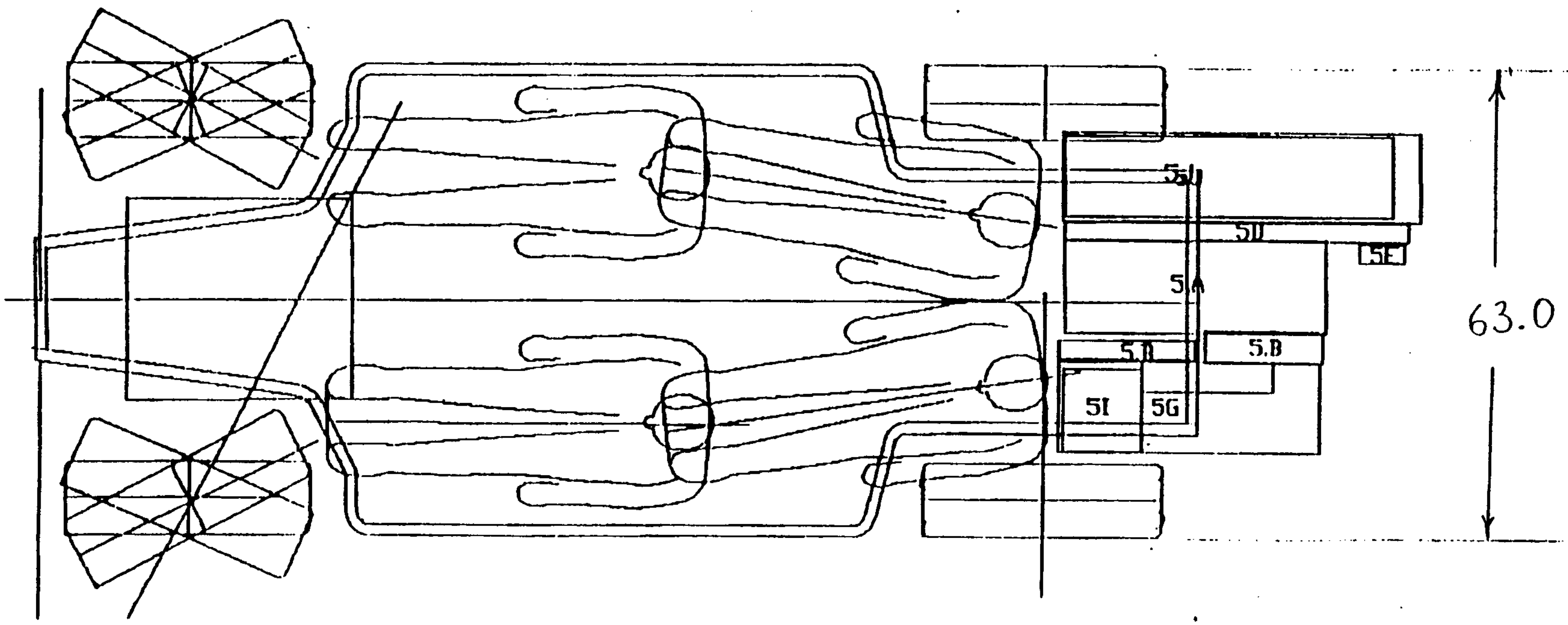
APPENDIX O

RST-V Variants

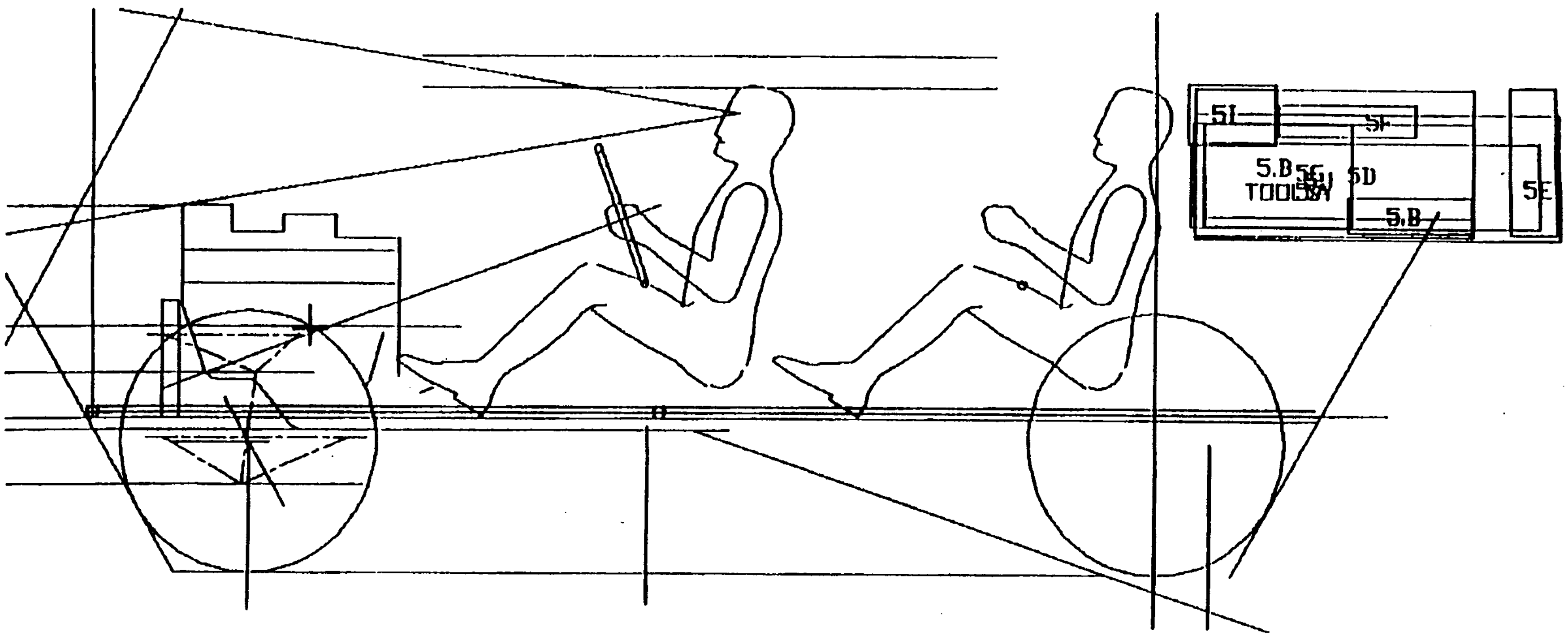
,65

Initial Vehicle Assessment - Seating Capacity

- 4 Man crew is too tight at 118" wheel base. Wheel base would have to be increased to about 142" minimum to allow for room of the back seat passengers.

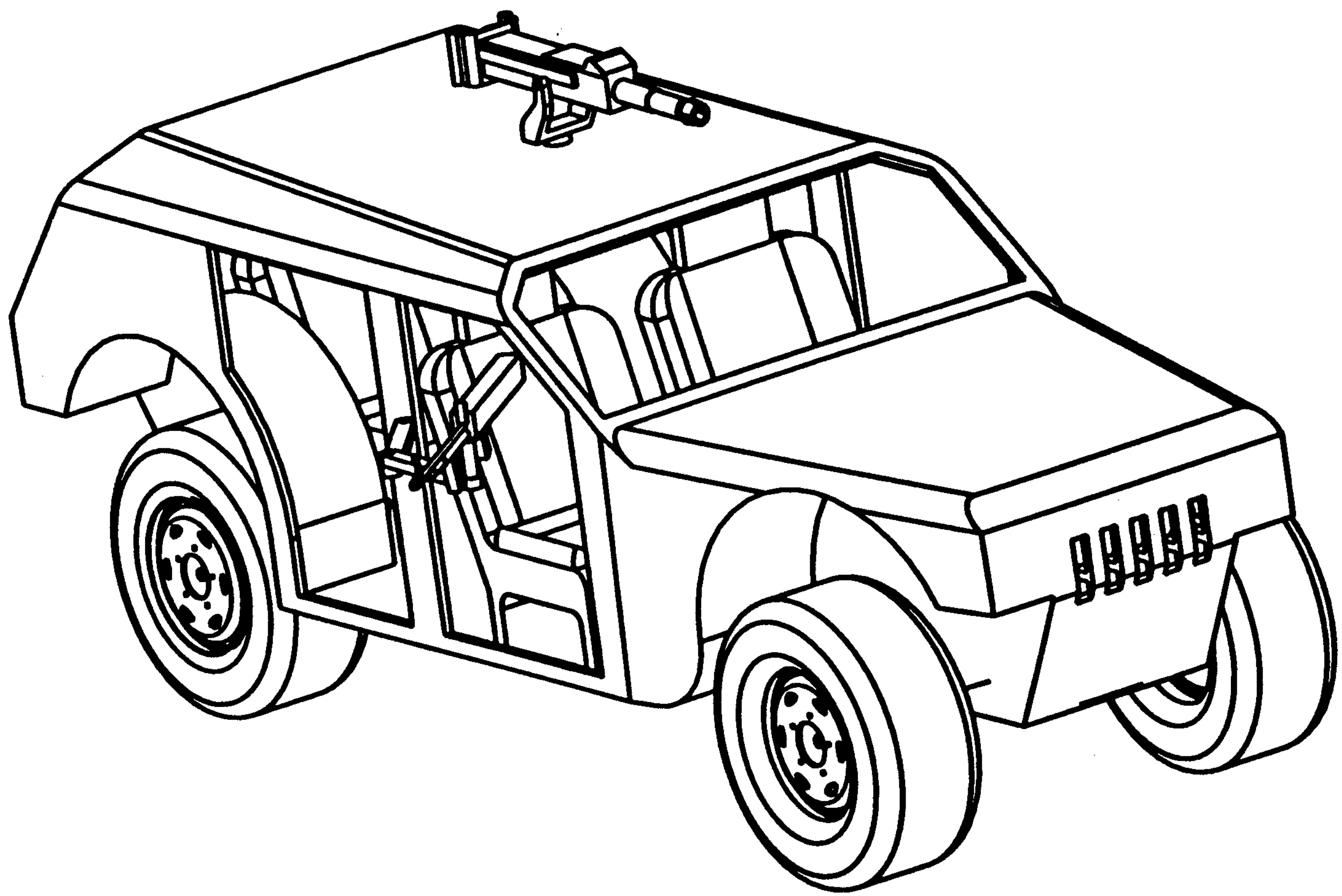


Initial Vehicle Assessment - Seating Capacity

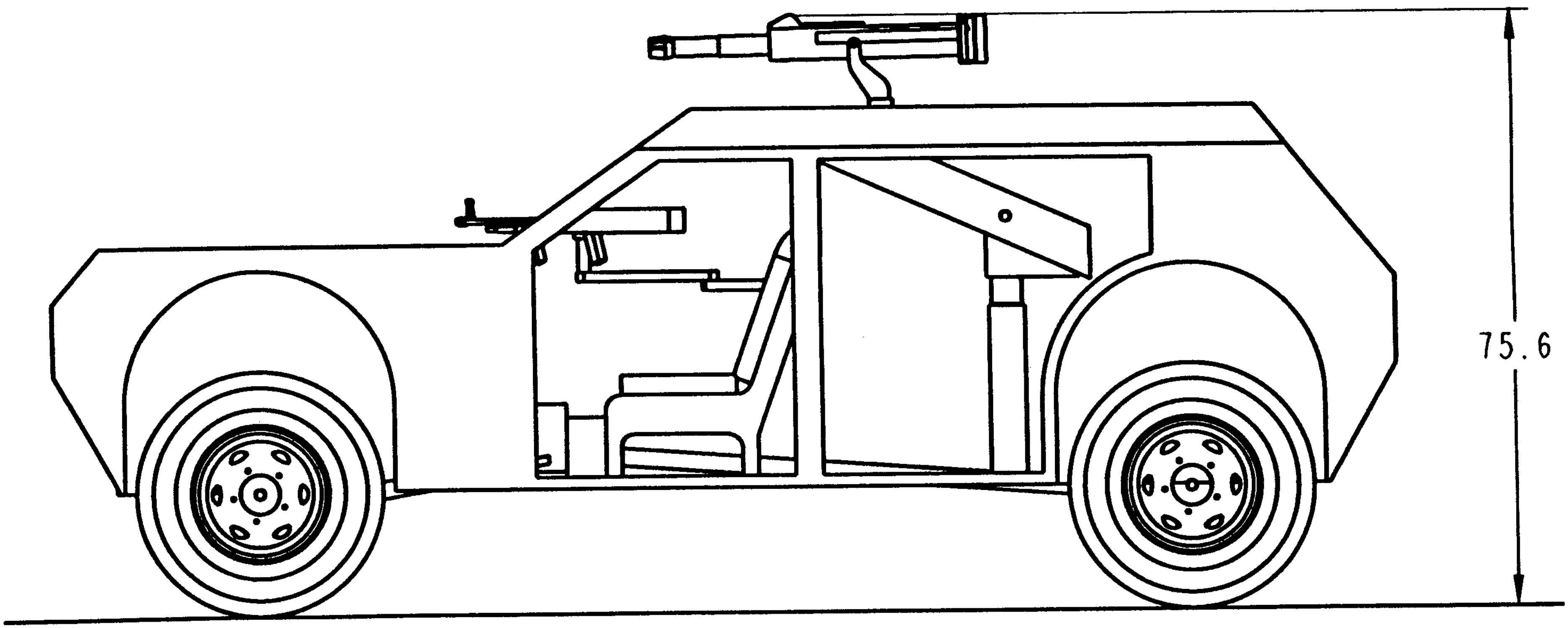


164

Subsystem Concept Development
Preliminary Vehicle Concept Models

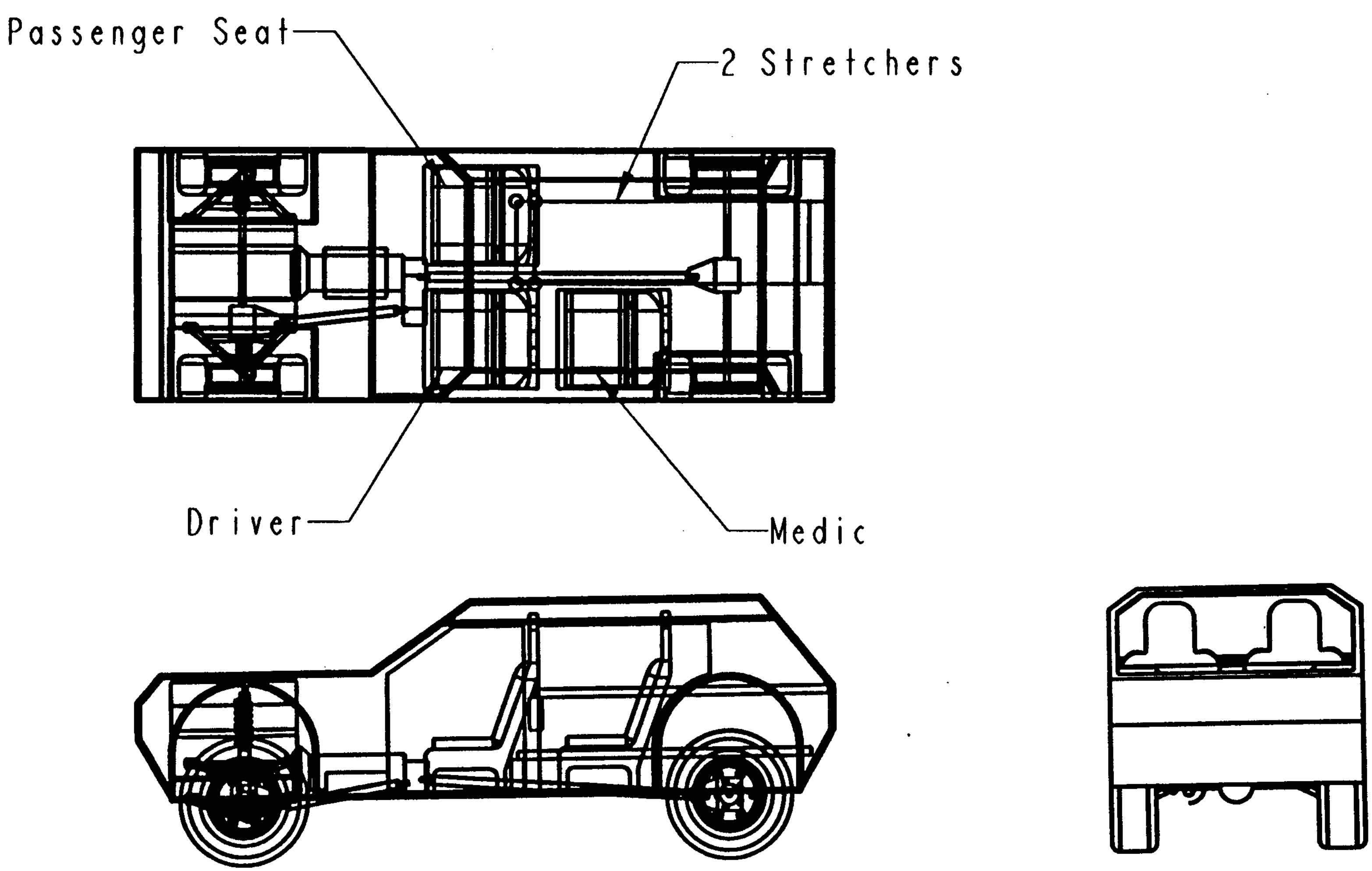


Subsystem Concept Development
Preliminary Vehicle Concept Models



Subsystem Concept Development

Preliminary Vehicle Concept Models



APPENDIX P

Detailed Vehicle Weight Breakdown

APPENDIX P
DETAILED VEHICLE WEIGHT BREAKDOWN

Category/Item	Qty.	Weight Each (Lbs)	Total Weight (Lbs)
EMPTY VEHICLE (Same for all Mission Variants)			
Hull			
Chassis Assembly	1	315.0	315.0
Body	1	120.0	120.0
Dash	1	10.0	10.0
Front Bumper	1	15.0	15.0
Rear Bumper	1	38.0	38.0
Front Trans. Skid Plate	1	3.0	3.0
Transmission Skid Plate	1	8.0	8.0
Engine Skid Plate	1	11.0	11.0
Floor Pan, Front	1	16.0	16.0
Floor Pan, Rear	1	16.0	16.0
Front Dust Wall	1	10.0	10.0
Side Basket	0	29.0	0.0
Gas Tank	2	15.0	30.0
Straps, Tank Holddown	4	2.0	8.0
Seat, Driver & Navigator	2	22.0	44.0
Seat Adjuster	3	3.0	9.0
Seat Belt Assembly	3	4.0	12.0
Passenger Seat	1	22.0	22.0
Clutch Pedal Assembly w/ Cyls.	0	4.0	0.0
Gas Pedal	1	1.0	1.0
Brake Pedal w/ Master Cyls.	1	8.0	8.0
Headlight	4	2.5	10.0
Blackout Lights	4	3.0	12.0
Hand Brake Assembly	1	4.0	4.0
Hull Weight Subtotal			722.0
Suspension & Steering			
Shock, front (Coil-over)	4	20.0	80.0
Shock Rear	4	20.0	80.0
Front Coil Springs	4	5.0	20.0
Rear Coil Springs	4	5.0	20.0
Trailing Arm, Rear	2	26.0	52.0
Tie Rod (set)	1	6.0	6.0
A-Arm Set	2	34.0	68.0
A-Arm Pivot Bushing Assembly	8	0.5	4.0
Spindle Assembly (set)	2	10.0	20.0
Bushing, IRS	4	0.3	1.0
Sleeve, IRS Bushing	2	0.5	1.0
Wheel Bearing Assembly, Front	2	9.5	19.0
Wheel Bearing Assembly, Rear	2	9.5	19.0
			0.0
Tire, Front	2	49.5	99.0
Tire, Rear	2	49.5	99.0
Wheel, Front (Al)	2	24.0	48.0
Wheel, Rear (Al)	2	24.0	48.0
Inner Tubes, Front	0	4.0	0.0
Inner Tubes, Rear	0	4.0	0.0
Power Steering Sys. Lines	1	3.0	3.0
Steering Box	1	35.0	35.0
Suspension & Steering (continued)			
Coupler, Steering	1	1.0	1.0
Steering Shaft	1	3.0	3.0
Ball Joints	4	1.5	6.0
Steering Bearing	2	1.0	2.0
U-Joint, Steering	2	0.5	1.0
Steering Wheel	1	2.0	2.0
Suspension & Steering Weight Subtotal			737.0

Category/Item	Qty.	Weight Each (Lbs)	Total Weight (Lbs)
Engine (Standard Propulsion System)			
Engine Assembly	1	687.0	687.0
Engine Accessories	1	90.2	90.2
Radiator	1	35.0	35.0
Radiator Hose	2	5.5	11.0
Fan Assembly	1	16.0	16.0
			0.0
Oil Cooler Assembly	1	8.0	8.0
Oil Filter	1	2.0	2.0
Oil Filter Mount	1	1.0	1.0
			0.0
Air Cleaner Assembly	1	7.0	7.0
Air Intake Box	1	2.0	2.0
Air Intake Screen	1	3.0	3.0
Hose, Airbox to Air Cleaner	1	3.0	3.0
Engine Weight Subtotal			865.2
Drivetrain (Standard Propulsion System)			
Transaxle	1	172.0	172.0
Front Differential	1	135.0	135.0
Driveshaft	1	15.0	15.0
CV Joint, Front Outer	2	8.0	16.0
CV Joint, Rear Outer	2	8.0	16.0
CV Joint, Front Inner (Turbo)	2	3.0	6.0
CV Joint, Rear Inner (Turbo)	2	3.0	6.0
Drive Axles, Front	2	8.0	16.0
Drive Axles, Rear	2	4.0	8.0
CRP Shifter Assembly	1	4.0	4.0
Caliper w/ Pads, Front	2	3.5	7.0
Caliper w/ Pads, Rear	2	3.5	7.0
Brake Rotor, Front	2	13.0	26.0
Brake Rotor, Rear	2	13.0	26.0
Park Brake Caliper	2	2.0	4.0
Drivetrain Weight Subtotal			464.0
Hybrid Electric Drive System - TBD			
Hybrid Electric Drive System Weight Subtotal			N/A
Built-in (Integral) Armor (Mine Attack)			
Built-in Armor Weight Subtotal			1047.0
Electrical Systems			
Battery	2	34.0	68.0
Wire Harness	1	35.0	35.0
Alternator, Heavy-Duty	1	75.0	75.0
Electrical Systems Weight Subtotal			178.0
EMPTY VEHICLE WEIGHT SUBTOTAL			4013.2

Category/Item	Qty.	Weight Each (Lbs)	Total Weight (Lbs)
ON-VEHICLE BASIC EQUIPMENT (Same for all Mission Variants)			
Communications/Navigation Equipment			
VHF radio (Transceiver, antenna, kit)	1	75.0	75.0
Intercom Harness & Control Boxes	1	16.5	16.5
Cables	1	10.0	10.0
Global Position System w/Antenna	1	4.4	4.4
Communications/Navigation Eqpt. Weight Subtotal			105.9
Controls & Displays			
Speedometer	1	1.0	1.0
Oil Pressure Gauge	1	0.5	0.5
Voltage Gauge	1	0.5	0.5
Water Temp. Gauge	1	0.5	0.5
Trans. Temp. Gauge	1	1.0	1.0
Hour Meter	1	1.0	1.0
Turn Signal Indicator	1	1.0	1.0
Compass	1	2.0	2.0
Fuel Gauge	2	1.0	2.0
Tachometer	1	1.0	1.0
Master Switch	1	1.0	1.0
Switch, Blackout	1	2.0	2.0
Switch, Headlight	1	0.5	0.5
Switch, Ignition	1	1.0	1.0
External Start Terminal	1	3.0	3.0
Controls & Displays Weight Subtotal	1		18.0
Accessories			
Spare Wheel & Tire	1	65.0	65.0
Jack	1	33.0	33.0
Towrope	1	4.0	4.0
Shovel	1	4.0	4.0
Axe	1	5.5	5.5
Tool Kit with Tools	1	25.0	25.0
Spare Parts	1	25.0	25.0
Fire Extinguisher and Mount	1	6.6	6.6
First Aid Kit	1	1.5	1.5
Lubricant Bottle	1	0.6	0.6
Camouflage Net w/Support	1	50.0	50.0
Accessories Weight Subtotal			220.2
ON-VEHICLE BASIC EQUIPMENT WEIGHT SUBTOTAL			344.1
ON-VEHICLE BASIC CONSUMABLES (Same for all Mission Variants)			
Fuel (In Fuel Tank)	21	6.5	136.5
Motor Oil (In Engine)	4	2.8	11.0
Motor Oil (Spare Quarts)	4	2.8	11.0
Other Lubricants (In Vehicle)	4	2.8	11.0
Other Lubricants (Spare Quarts)	4	2.8	11.0
Coolant (In Radiator)	6	2.8	16.5
ON-VEHICLE BASIC CONSUMABLES WEIGHT SUBTOTAL			197.0

VEHICLE CURB WEIGHT (Same for all Mission Variants) 4554.3 Lbs.

Category/Item	RST-V Qty	RST-V Weight (Lbs)	Strike Qty	Strike Weight (Lbs)	Personnel Qty	Personnel Weight (Lbs)	Log & Litters Qty	Log & Litters Weight (Lbs)
VEHICLE-MOUNTED WEAPONS & AMMUNITION								
M60E3 7.62mm Machine Gun								
M60E3	1	20.8	1	20.8	1	20.8	1	20.8
Scissors Swing Arm Mount	1	20.0	1	20.0	1	20.0	1	20.0
Gun Mount w/200rd Ammo Can	1	12.0	1	12.0	1	12.0	1	12.0
Cans, Ready Ammo	2	8.0	2	8.0	2	8.0	2	8.0
Cans, Stowed Ammo	2	8.0	8	32.0	2	8.0		0.0
Day / Night Sight	1	11.0	1	11.0	1	11.0	1	11.0
Spare Barrel	1	12.0	1	12.0	1	12.0	1	12.0
Weapon CES	1	3.0	1	3.0	1	3.0	1	3.0
M60E3 7.62mm Machine Gun Weight Subtotal		94.8		118.8		94.8		86.8
M60E3 7.62mm Ammunition								
Ammunition - Ready (8.75#/100)	400	35.0	400	35.0	400	35.0	400	35.0
Ammunition - Stowed (8.75#/100)	400	35.0	1600	140.0	400	35.0	0	0.0
M60E3 Ammunition Weight Subtotal	800	70.0	2000	175.0	800	70.0	400	35.0
M2 .50 Cal Machine Gun								
M2 MG w/QCB		84.0	1	84.0				
Pedestal Mount		40.0	1	40.0				
Gun Mount w/200 rd Ammo Can		20.0	1	20.0				
Cans, Ready Ammo		16.0	2	16.0				
Cans, Stowed Ammo		16.0	8	64.0				
Day / Night Sight		11.0	1	11.0				
Spare Barrel		24.0	1	24.0				
Weapon CES		2.2	1	2.2				
M2 .50 Cal Machine Gun Weight Subtotal		213.2		261.2				
M2 .50 Cal Ammunition								
Ammunition - Ready (.29# ea)	200	58.0	200	58.0				
Ammunition - Stowed (.29# ea)	200	58.0	800	232.0				
M2 .50 Cal Ammunition Weight Subtotal	400	116.0	1000	290.0				
Mk19 40mm AGL								
Mk19 AGL			1	75.6				
Pedestal Mount			1	40.0				
Gun Mount w/50 rd Ammo Can			1	20.0				
Cans, Ready Ammo			2	16.0				
Cans, Ready Ammo			6	48.0				
Day / Night Sight			1	11.0				
Spare Barrel			1	23.9				
Weapon CES			1	2.2				
MK19 40mm AGL Weight Subtotal (Not Implemented)				236.7				
Mk19 40mm Ammunition								
Ammunition - Ready (.75# ea)			96	72.0				
Ammunition - Stowed (.75# ea)			288	216.0				
MK19 40mm Ammunition Weight Subtotal (Not Implemented)			384	288.0				
GAU-19 .50 Cal Gatling Gun								
GAU-19			1	76.0				
Pedestal Mount			1	40.0				
Gun Mount w/600 rd Ammo Can			1	20.0				
Cans, Ready Ammo			2	16.0				
Cans, Stowed Ammo			18	144.0				
Day / Night Sight			1	11.0				
Spare Barrel			1	23.9				
Weapon CES			1	2.2				
GAU-19 .50 Cal Gatling Gun Weight Subtotal (Not Implemented)				333.1				
GAU-19 .50 Cal Ammunition								
Ammunition - Ready (.29# ea)			200	58.0				
Ammunition - Stowed (.29# ea)			1800	522.0				
GAU-19 .50 Cal Ammunition Weight Subtotal (Not Implemented)			2000	580.0				

Category/Item	RST-V Qty	RST-V Weight (Lbs)	Strike Qty	Strike Weight (Lbs)	Personnel Qty	Personnel Weight (Lbs)	Log & Litters Qty	Log & Litters Weight (Lbs)
VEHICLE-MOUNTED WEAPONS & AMMUNITION (continued)								
M230B LF 30mm Chain Gun								
M230B			1	384.0				
Pedestal Mount			1	80.0				
Gun Mount w/90 rd Ammo Can			1	80.0				
Cans, Ready Ammo			3	24.0				
Cans, Stowed Ammo			12	96.0				
Day / Night Sight			1	11.0				
Spare Barrel			1	60.0				
Weapon CES			1	3.0				
M230B LF 30mm Chain Gun Weight Subtotal (Not Implemented)				738.0				
M230B LF 30mm Ammunition								
Ammunition - Ready (.78# ea)			90	70.2				
Ammunition - Stowed (.78# ea)			360	280.8				
M230B LF 30mm Ammunition Weight Subtotal (Not Implemented)			450	351.0				
HICLE-MOUNTED WEAPONS & AMMO WEIGHT SUBTOTAL		494.0		845.0		164.8		121.8
PERSONNEL & PERSONAL EQUIPMENT								
Crew & Passengers								
Crew & Passengers Weight Subtotal (NATO Average)	3	525.0	3	525.0	5	875.0	3	525.0
Personal Equipment								
Personal Weapon	3	24.0	3	24.0	5	40.0	2	16.0
Personal Weapon CES	3	2.4	3	2.4	5	4.0	2	1.6
Ammunition (5x30 rd magazines)	6	30.0	6	30.0	23	115.0	4	20.0
Helmet	3	13.2	3	13.2	5	22.0	2	8.8
Armored Vest	3	48.0	3	48.0	5	80.0	2	32.0
Personal equipment & clothes	3	195.0	3	195.0	5	325.0	2	130.0
Binoculars	2	4.4	2	4.4	3	6.6	1	2.2
Personal Equipment Weight Subtotal		317.0		317.0		592.6		210.6
PERSONNEL & PERSONAL EQUIPMENT WEIGHT SUBTOTA		842.0		842.0		1467.6		735.6
CONSUMABLES								
Combat Ration	9	9.0	9	9.0	15	15.0	6	6.0
Hexamine Stove	3	1.5	3	1.5	5	2.5	6	3.0
Water (in 5 Gal Jerrycan)	4	150.0	2	75.0	2	75.0	3	112.5
CONSUMABLES WEIGHT SUBTOTAL		160.5		85.5		92.5		121.5
CONFIGURABLE ARMOR (Amount available under weight threshold)								
CONFIGURABLE ARMOR WEIGHT SUBTOTAL		0.0		882.0		882.0		0.0
OTHER MISSION EQUIPMENT								
Communication/Navigation								
MILSATCOM Terminal, kit, antenna & CES	1	40.0	1	40.0				
MILSATCOM Modem	1	11.0	1	11.0				
Batteries - VHF (Lithium 8Ah)	1	3.3	1	3.3	1	3.3	1	3.3
Remote Equipment	1	14.0	1	14.0	0	0.0	1	14.0
COMSEC Interface	1	17.6	1	17.6	0	0.0	1	17.6
COMSEC Device, Mount & Adapter	1	4.4	1	4.4	0	0.0	1	4.4
Data input device	1	11.0	1	11.0	0	0.0	1	11.0
Cables	1	10.0	1	10.0	1	10.0	1	10.0
Manpack and VHF CES	1	16.5	1	16.5	1	16.5	1	16.5
Communication/Navigation Weight Subtotal		127.8		127.8		29.8		76.8
Surveillance & Observation Equipment								
Mission Equip (e.g. Laser Designator)	1	5.5		0.0		0.0		0.0
Device Tripod	1	4.4		0.0		0.0		0.0
Night Vision Goggles	3	13.2	3	13.2	2	8.8	2	8.8
Night Vision Binoculars	1	4.4	1	4.4	1	4.4	1	4.4
Laser Range Finder	1	4.4	1	4.4		0.0		0.0
Batteries for Observation Devices	1	22.0	1	22.0		0.0		0.0
Searchlight w/Power Supply	0	0.0	0	0.0	1	26.4	1	26.4
Surveillance & Observation Eqpt. Weight Subtotal		53.9		44.0		39.6		39.6
Logistics Equipment & Litters								
Logistics Equipment & Litters Weight Subtotal								900.0
OTHER MISSION EQUIPMENT WEIGHT SUBTOTAL		181.7		171.8		69.4		1016.4
PAYLOAD WEIGHT (lbs)		1678.2 Lbs		2826.3 Lbs.		2676.3 Lbs		1995.3

180